Global Water Research Coalition

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MBR for Municipal Wastewater Treatment

Report of the GWRC Research Strategy Workshop

GLOBAL WATER RESEARCH COALITION
STOWA

MBR FOR MUNICIPAL WASTEWATER TREATMENT

REPORT OF THE GWRC RESEARCH STRATEGY WORKSHOP

Prepared by:
STOWA and Witteveen+Bos Consulting Engineers (the Netherlands)
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Global Water Research Coalition
Alliance Hous
12 Caxton Street
London SW1H 0QS
United Kingdom
Phone: +44 207 654 6645
www.globalwaterresearchcoalition.net

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GLOBAL WATER RESEARCH COALITION

GLOBAL COOPERATION FOR THE GENERATION OF WATER KNOWLEDGE

GWRC is a non-profit organization that serves as a collaborative mechanism for water research. The benefits that the GWRC offers its members are water research information and knowledge. The Coalition focuses on water supply and wastewater issues and renewable water resources: the urban water cycle.

The members of the GWRC are: the Awwa Research Foundation (US), CRC Water Quality and Treatment (Australia), EAWAG (Switzerland), KIWA (Netherlands), Suez Environment- CIRSEE (France), Stowa - Foundation for Applied Water Research (Netherlands), DVGW - TZW Water Technology Center (Germany), UK Water Industry Research (UK), Veolia- Anjou Recherché (France), Water Environment Research Foundation (US), Water Research Commission (South Africa), WateReuse Foundation (US), and the Water Services Association of Australia.

These organizations have national research programs addressing different parts of the water cycle. They provide the impetus, credibility, and funding for the GWRC. Each member brings a unique set of skills and knowledge to the Coalition. Through its member organizations GWRC represents the interests and needs of 500 million consumers.

GWRC was officially formed in April 2002 with the signing of a partnership agreement at the International Water Association 3rd World Water Congress in Melbourne. A partnership agreement was signed with the U.S. Environmental Protection Agency in July 2003. GWRC is affiliated with the International Water Association (IWA).

DISCLAIMER

GWRC members jointly funded this study. GWRC and its members assume no responsibility for the content of the research study reported in this publication or for the opinion or statements of fact expressed in the report. The mention of trade names for commercial products does not represent or imply the approval or endorsement of GWRC and its members. This report is presented solely for informational purposes.

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PROJECT TEAM

Lead agent: Cora Uijterlinde, STOWA, The Netherlands
Frans Schulting, GWRC, The Netherlands
Peter de Jong, Witteveen+Bos, The Netherlands
Arjen van Nieuwenhuijzen, Witteveen+Bos, The Netherlands
Herman Evenblij, Witteveen+Bos, The Netherlands

Participant	*Organisation*	*Country*	*Invited by/Representing*
Samer Adham	Montgomery Watson Harza	USA	WRF, WERF
Emile Cornelissen	KIWA	NL	KIWA
Eve Germain	Thames Water	UK	UKWIR
Adriano Joss	EAWAG	CH	EAWAG
Kees de Korte	DWR	NL	STOWA
Boris Lesjean	BCCW	D	Anjou Recherche
Pia Lipp	TZW/DVGW	D	TZW
Francis Luck	BCCW	D	Anjou Recherche
Pete Pearce	Thames Water	UK	UKWIR
Philip Schyns	WRIJ	NL	STOWA

PARTICIPANTS OF THE WORKSHOP, **LEFT TO RIGHT: HERMAN EVENBLIJ, KEES DE KORTE, ADRIANO JOSS, FRANCIS LUCK, EVE GERMAIN, PETE PEARCE, FRANS SCHULTING, CORA UIJTERLINDE, PHILIP SCHYNS, EMILE CORNELISSEN, SAMER ADHAM, BORIS LESJEAN, PIA LIPP, ARJEN VAN NIEUWENHUIJZEN**

EXECUTIVE SUMMARY

The past ten years have seen a lot of developments in membrane bioreactor (MBR) technology. Much of the research activities that were carried out, aimed at application of the technology in full-scale wastewater treatment. This has resulted in the realisation of some 75 full-scale installations world wide, with a wide range of treatment capacities.
Due to the growing interest in MBR, the members of the Global Water Research Coalition (GWRC) selected MBR as a priority area in the GWRC's research agenda. The Board of Directors of the GWRC initiated a project with the aim of reviewing the present knowledge of MBR and to organise a workshop to develop a phased research strategy.
The opening of the MBR at Varsseveld wwtp (The Netherlands) was seized by the GWRC to prepare a state of science report with regard to MBR. In a two-day workshop the current state of science and the member activities were discussed and used to identify future research needs.

Within the GWRC membership and associated organisations a vast amount of knowledge and know-how is available. The exchange of knowledge and experience with design and operation of MBR installations is however rather limited and can be enhanced by setting up a Knowledge Base. This knowledge base can be used to develop a Decision Support Tool, which enables decision-makers to make a fair comparison of different available techniques

Among the most important research topics, effluent quality and membrane fouling come out as first priority.
Fouling is regarded as a major problem in MBR. Operational strategies to cope with fouling problems are primarily empirical, and scientific knowledge on underlying processes is lacking. Membrane fouling is dependent on many variables and can be minimised by optimum design and good operation, appropriate pre-treatment and cleaning strategies. There are serious questions as to whether the current operating window is at an optimum.

Innovative water cycle concepts including MBR technology are likely to broaden the application range of the technology. A forecast of the global status and possibilities and limitation of MBR as part of the urban water cycle could give guidance to further development of this technology. Existing ideas and projects like nanofiltration MBR and anaerobic MBR should be evaluated and further investigated.

Based on the outcome of the workshop, four project themes were defined:

1 development of an MBR knowledge base for municipal wastewater treatment;
2 decision Support Tool for municipal MBR technology choice;
3 effluent quality of MBRs;
4 scenario studies 2030: Identification of future concepts of wastewater management with innovative MBR technologies.

1

INTRODUCTION

1.1 BACKGROUND

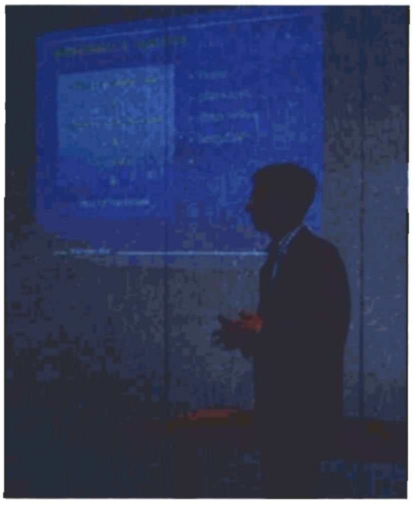
The development of membrane bioreactor (MBR) technology has made major steps in the past ten years. As a result of this, the field of application has broadened towards the municipal wastewater treatment sector. To date, about 75 full-scale installations (with a capacity of more than 100 m^3/day) for the treatment of municipal wastewater are in operation or under construction worldwide.
In conjunction with this development there has been a lot of research activity in the field of MBR technology. The Board of Directors of the Global Water Research Coalition (GWRC) determined this technology to be of priority for collaborative research and decided to conduct a project with the aim to:

- determine the current state of the science in the field of MBR;
- develop a phased research strategy represented by priority research projects.

STOWA, the Dutch organisation co-ordinating the research activities on behalf of the Dutch Water Authorities, was as GWRC member assigned with the lead of the project. Witteveen+Bos Consulting Engineers was contracted to prepare a State of the Science report with regard to MBR technology. The State of the Science report was sent around to the GWRC members and served as a basis for the Workshop which was held in Doetinchem/Arnhem, April 26/27 with representatives of GWRC members and invited experts. This workshop report summarises the presentations and findings of the MBR Research Strategy Workshop.

1.2 OBJECTIVE AND APPROACH OF THE WORKSHOP

The objective of the workshop was to present the current state of knowledge on MBR for municipal wastewater treatment and to identify knowledge gaps and research needs in this field. Based on the knowledge gaps and missing links, a research strategy was developed and a set of project proposals for joint actions was devised.



1.3 THE WORKSHOP

The first day of the workshop was dedicated to the determination and discussion of the current State of the Science with regard to MBR. The draft version of the report was presented and subsequently discussed according to the identified research topics.
Each participant introduced the research activities of the organisation they were representing. In the afternoon session the results were summarised in a 'knowledge map'. Based on this list of issues, the second day was used to specify knowledge gaps and research needs. Four major research topics were selected and addressed in preliminary project proposals.

2

CURRENT KNOWLEDGE ON MBR

2.1 INTRODUCTION

As first step to develop the GWRC research strategy on Membrane Bioreactors the current state of knowledge was discussed and existing knowledge gaps were identified. Building blocks in this process were the GWRC report *State of the Science on MBR* (GWRC 2005), the information presented at the International MBR Symposium in Varsseveld (April 2005) and the presentations of the member activities during the workshop. In the following paragraphs both the presentations and the input from the discussions are summarised. As final result the knowledge map on MBR ("what do we know and what not") is presented.

2.2. CURRENT ACTIVITIES BY PARTICIPANTS

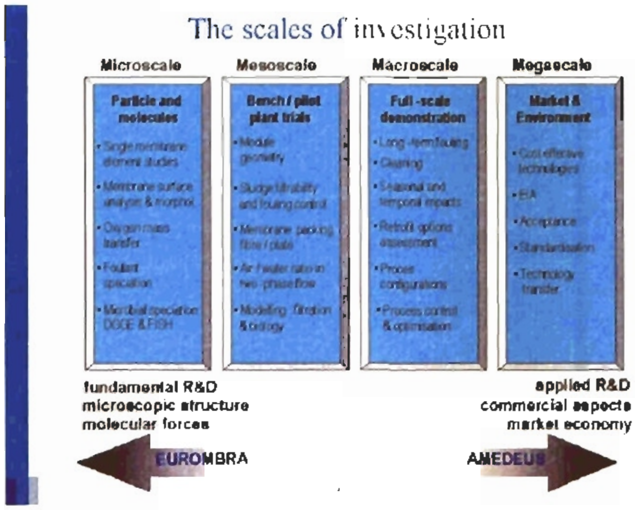
Each of the participants presented the relevant research activity of the organisation they were representing.

2.2.1. RESEARCH CONSORTIA AMEDEUS/EUROMBRA – LESJEAN /JOSS

Two consortia of European research institutes submitted a proposal for the 3rd Call of the 6th Framework Programme Priority Global Changes and Sustainable Development. The two projects turned out to be complementary for the greater part. Therefore both proposals were selected and asked to be rewritten in order to omit overlapping activities.

The AMEDEUS consortium focuses on 'the Acceleration of Membrane Development for Urban Sewage Purification'. One of the aims is fostering development of competitive European MBR-filtration technologies to secure MBR market shares. The overall objective of EUROMBRA is to develop a cost-effective, sustainable solution for new, efficient and advanced municipal wastewater treatment based on MBR technology. This will be achieved through a multi-faceted, concerted and cohesive research programme explicitly linking key limiting phenomena (fouling, clogging) observed and quantified on the micro-, meso and macroscale. Figure 2.1 illustrates the scales of investigation and the involvement of the two research consortia.

FIGURE 2.1 DIVISION OF RESEARCH ACTIVITIES BY EUROMBRA AND AMEDEUS



The two consortia together consist of 28 institutes, consisting of universities, R&D centres, end-users and SME's (small to medium enterprises).

2.2.2 KIWA WATER RESEARCH – CORNELISSEN

KIWA Water Research carries out research for the drinking water companies in the Netherlands. In the field of membrane technology there is a lot of experience in the study of fouling phenomena (biofouling, particulate fouling, organic fouling and scaling). Further expertise is in the field of integrity. Another topic is the removal capacity of membranes for different micro pollutants. Currently there is renewed interest in ceramic membranes.

2.2.3 TECHNOLOGIE ZENTRUM WASSER (TZW) – LIPP

TZW is an independent non-profit organisation for drinking water-related research. TZW is part of the German Technical and Scientific Association for Gas and Water. The mission of the TZW is transferring science to the water industry. Among working fields are analytical chemistry, microbiology and membrane technology. Within the filed of membrane technology, membrane fouling and cleaning of ultrafiltration systems are investigated with lab-scale and pilot units.

2.2.4 KOMPETENZZENTRUM WASSER BERLIN - LUCK/LESJEAN

KompetenzZentrum Wasser Berlin (KWB) - Luck/Lesjean: The Berlin Centre of Competence for Water is a public/private owned R&D centre between the city of Berlin, the Berliner Wasserbetriebe and the Water Company Veolia. Current activities in the field of MBR comprise advanced biological nutrients removal and the development of small scale MBRs for communities that are not yet connected to the sewer/ A demonstration project with EU-LIFE subsidy is being carried out with a MBR plant with a capacity of 250 p.e. KWB will co-ordinate the European project AMEDEUS dedicated to MBR development.

2.2.5 EAWAG – JOSS

EAWAG is the Swiss Federal Institute for Environmental Science and Technology. Eawag's task as the national research center for water pollution control is to ensure that:

- concepts and technologies pertaining to the use of natural waters are continuously improved;
- ecological, economical and social water interests are brought into line.

Multidisciplinary teams of specialists in the fields of Environmental Engineering, Natural and Social Sciences jointly develop solutions to environmental problems. The acquired knowledge and know-how is transmitted nationally and internationally by publications, lectures, teaching, and consulting to the private and public sector.
The environmental engineering division of EAWAG works on current and future aspects of urban hydrology, wastewater and drinking water treatment, as well as water pollution control. Together with the division urban water management (UWM) the goal is, to develop sustainable concepts of the water and nutrient cycle in urban settlements.
EAWAG is operating a membrane bioreactor pilot (100 population equivalent) since 10th July 2001. The following aspects are approached:

- design, modelling and operation of biological N and P removal at different sludge ages (15, 30 and 60 days);
- optimisation of the operation and chemical cleaning of the membrane modules;
- comparing the operation of 3 standard modules operated in parallel (Kubota, Mitsubishi and Zenon);
- assessment of the micro-pollutant removal capacity and comparison with the conventional activated sludge process with sedimentation (EU project POSEIDON).

2.2.6 THAMES WATER/UKWIR – PEARCE/GERMAIN

The activities on MBR by UK Water Industry Research (UKWIR) were presented at the MBR symposium preceding the workshop and are presented in Appendix V. UKWIR facilitates collaborative research for UK water operators. UKWIR's members comprise 24 water and sewerage undertakers in England and Wales, Scotland and Northern Ireland. The objectives of the organisation are to:

- identify research requirements to meet the water industry's strategic business needs;
- procure the research competitively;
- work with the water industry's regulators;
- provide value for money for the contributors;
- transfer the research outputs to contributors.

Thames Water recently completed a four year research programme, looking at control of short term fouling on hollow fibre membranes by studying biological and physical effects.

2.2.7 WRF/WERF– ADHAM

The Water Reuse Foundation co-ordinates the majority of the water reuse research in the US. Water Environment Research Federation covers a broad range of research fields in wastewater treatment. Several research projects on MBR are carried out, many of them with regard to reuse applications. Emerging pollutants of concert are endocrine disrupting compounds, pharmaceutical active compounds and personal care products. One of the WERF activities is a yearly publication of review articles on wastewater treatment. The MBR articles are discussed in the GWRC State of Science report (GWRC, 2005).

2.2.8 WATER AUTHORITY DWR – DE KORTE

The Water Authority DWR is responsible for surface water quality and wastewater with the Water Board Amstel, Gooi en Vecht in the Netherlands. In the year 2001 DWR started a MBR pilot project at the wwtp Hilversum. The pilot installation is equipped with Kubota membranes and has been in operation for more than 4 years. To date, the design of a full scale MBR treatment plant is being made and the commissioning of the plant is dated start 2008.

2.2.9 WATERBOARD RIJN EN IJSSEL - SCHYNS

The Waterboard Rijn en IJssel has recently commissioned the MBR demonstration plant at Varsseveld. This project serves as a demonstration for the other water boards to obtain experiences with larger scale MBR in the specific Dutch situation. To this aim a broad scoped research programme is being carried out together with TNO, Delft University of Technology and Wetsus.

2.2.10 STOWA – UIJTERLINDE

STOWA is the organisation co-ordinating the research activities from the Water Boards in the Netherlands, and is therefore involved in the project of the Waterboard Rijn en IJssel. Furthermore, STOWA co-ordinated pilot plant trials at the wastewater treatment plants of Beverwijk, Maasbommel and Leeuwarden. The Leeuwarden project is especially of interest since the MBR is treating wwtp effluent. The developing biomass is for example very efficient in removing 17α-ethinylestradiol.

2.3 STATE OF THE SCIENCE

During the past 5 years a lot of research activity was carried out in the field of MBR technology. The GWRC-report *State of the Science on MBR* (GWRC 2005) presents an overview of the research activities of the past 5 years.

Ranging from purely scientific lab-scale work to full scale operational optimisation studies, the range of research topics covers almost all disciplines in wastewater treatment and membrane technology. To focus the GWRC review, some 130 scientific papers were selected with respect to the relevance for the development of full scale MBRs for municipal wastewater treatment.

2.3.1 FOULING

Fouling, its control and prevention and membrane cleaning are by far the most investigated topics in MBR research. Since the membrane separation step can not be by-passed and failure leads to zero-production it forms the bottleneck of the MBR process.

There have been several approaches to cope with fouling in MBR. These approaches can be divided in two groups:

1) *Optimisation of the existing process via operational measures.*

Quite important in this field is the pre-treatment of the system. Due to the configuration of the membrane modules larger particles, hairs and fibres tend to accumulate within the membrane tank and cause a loss of available permeation area and interfere with the sludge flow.

2) *Scientific research into fouling mechanisms, fouling substances and their origin.*

The major fouling mechanisms in MBR are cake layer formation and adsorption to the membrane surface, the latter resulting in a reduction of the available permeation area. Cake layer formation can usually be controlled by the continuous coarse bubble membrane aeration. Adsorption is regarded a function of the total produced volume and can be addressed by the maintenance cleaning.

Hydraulic and concentration peaks in the influent turn out to be difficult to handle for an MBR. In those cases where storm weather has to be treated, the effects of a storm weather event are experienced as a sudden drop in permeability of the system.

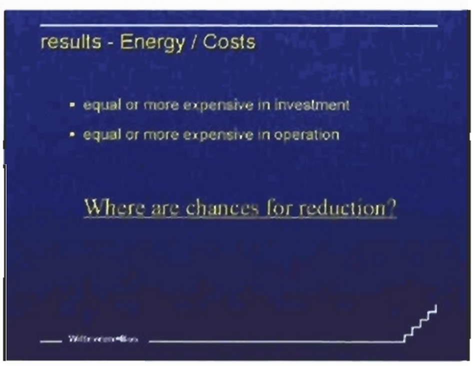
With regard to the substances that are involved in membrane fouling, determining the fraction of the mixed liquor, responsible for membrane fouling made a step forward. This fraction consists of cell fragments, macromolecules and bacterial cells, which are able to form aggregates when concentrated at the membrane surface.

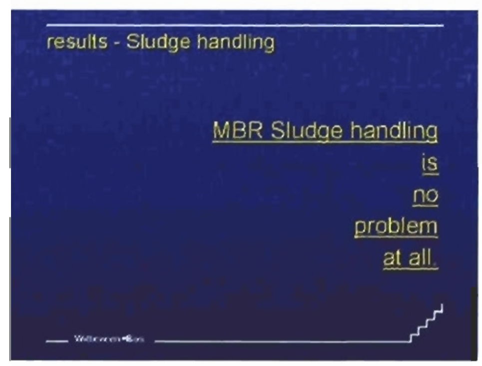
The general feeling about fouling studies is summarised in observing that although a lot of research effort was put into membrane fouling, definite answers are not yet found. It must be remarked that much of the research work was not or only to a limited extent, co-ordinated. A global co-ordination of MBR research is desirable. The regular exchange via scientific conferences is not enough. Too many researches are merely repeating former work.

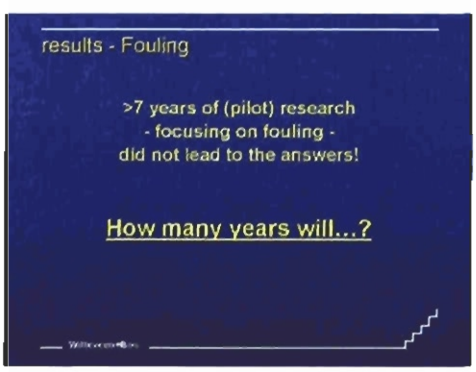
This last fact brings in another question, concerning the use of pilot plant research. Several experiences show that problems during pilot scale research are not occurring in full-scale application, and *vice versa*. This raises the question whether pilot plant research is the appropriate means to further facilitate MBR application.

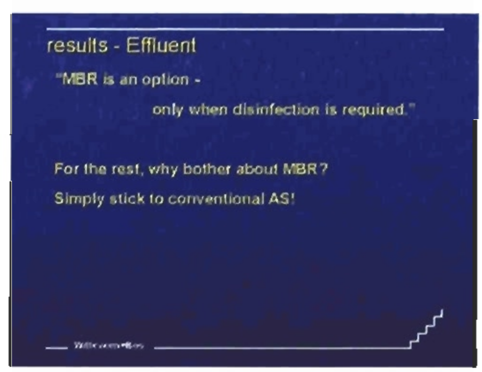
2.3.2 EFFLUENT QUALITY

The high obtainable effluent quality is the most frequently mentioned advantage of the MBR technique. Both in scientific literature and by vendors. Originally it was hypothesised that the uncoupling of Solids Retention Time and Hydraulic Retention Time would lead to growth of microbial species that would for example be washed out in a conventional secondary clarifier. Although a significant change in population was observed, the occurring degradation proces-









ses were not different from those encountered in conventional activated sludge (CAS) systems. Furthermore, practical considerations have led to the application of conventional SRTs.

SOLIDS/COLLOIDS REMOVAL

The most significant advantage of MBR is materialised by the fact that the membrane produces an effluent that is particle free. With respect to its disinfecting capacity, different and sometimes contradictory results exist. Generally it can be said that MBR effluent complies with the European bathing water guidelines in terms of hygienic safety. The strong point of MBR in terms of effluent quality is its ability to remove all suspended, colloidal matter and pollutants bound to this fraction.
The conclusion of these considerations was formulated as follows:
"With respect to effluent quality only when disinfection is compulsory, MBR has a real advantage. In other cases the differences are smaller and a convential activated sludge system is a better option."

There were great expectations of the almost 'magic' interaction between membranes and activated sludge, supposedly leading to extremely high effluent quality. This turns out to be beside the truth and some differentiations can be made:

- in cases where low Nitrogen an Phosphorus concentrations must be reached, the membrane prevents washing out of sludge fragments, thus ensuring a constant effluent quality;
- it is important to realise that a comparison of MBR with a conventional activated sludge system (CAS) system should not be made, since MBR is meant as an upgrading of the CAS. Therefore comparing MBR to CAS plus other (tertiary) treatment steps should assess the merits of MBR. If this is done, MBR will be competitive sooner;
- one of the strong points of MBR in terms of effluent quality is the stability. Bulking sludge does not necessarily lead to a decrease in effluent quality, because of the membrane. Thus, although the absolute effluent quality may not be significant higher, it is definitely more stable.

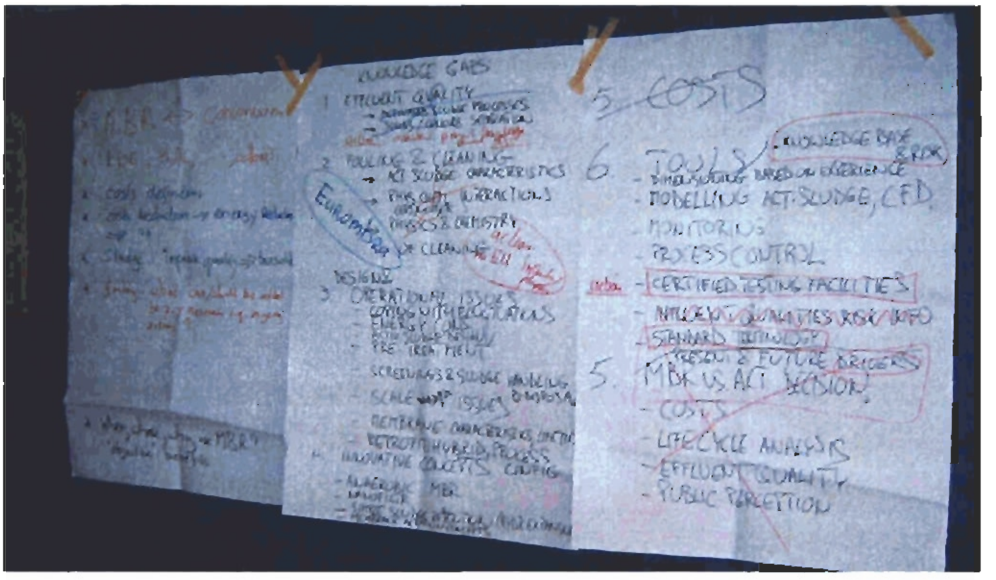
EDC/MICRO POLLUTANTS

A current topic of major concern is the removal of Endocrine Disrupting Compounds (EDC). MBR was expected to show high removal efficiencies for these substances as well as other priority substances as indicated by the European Water Framework Directive. Recent researches and measurement campaigns have slightly changed the view on this subject. Apart from difficulties in measuring EDC, it is supposed that MBR can remove these compounds only to a limited extent. Other compounds, like pesticides, show removal efficiencies similar to those in conventional activated sludge systems. Until now it is unknown in which fraction these substances occur in the wastewater. Based on the analyses it seems likely that these substances are primarily in soluble form, i.e. smaller than the membrane pore size.

Results of recent measurements indicate that MBR is not really appropriate to remove micro pollutants.

2.3.3 ENERGY/COST ISSUES

The amount of energy that is consumed per unit volume of effluent is relatively high for MBR and lies in the range of 1.5 - 2.5 kWh/m^3, although lower values are reported in literature. For conventional activated sludge systems the energy requirements are in the range 1.0-1.2 kWh/m^3. In this case it is again a matter of definition: where are the system boundaries, is the effluent quality the same for both systems, etc.



Some steps are made with respect to decreasing energy demand of the MBR system. Intermittent aeration of the membrane modules, double deck configuration (plate and frame membranes) and reducing the MLSS concentration have contributed to an overall decrease in energy consumption.

The operational costs of an MBR are related to the energy demand of the system. Although they are closely related, it seems useful to make a strict separation between energy issues and cost issues.

Cost issues must be divided in capital cost and operational cost. The capital cost for MBR are high, because of the membranes and the equipment needed to operate the membranes.

The cost minimisation of the MBR system will be closely related to optimisation of the hydraulic performance. Optimisation of the hydraulic performance includes: higher operational permeate fluxes (lower installed membrane surface) and better fouling control.

2.3.4 SLUDGE/WASTE HANDLING

The problems and solutions concerning waste activated sludge treatment are varying per country. In Germany there are good experiences with the dewaterability of the waste sludge from MBRs. In the European situation it is not regarded a real scientific research topic. In the USA however, there is a great concern about this topic, since there is a totally different view on the treatment of biosolids. In the Netherlands, waste activated sludge is ultimately incinerated and may not be used as fertiliser. In the USA, there is a trend towards reuse of these substances, which makes it necessary to avoid the presence of e.g. heavy metals and organic micro pollutants.

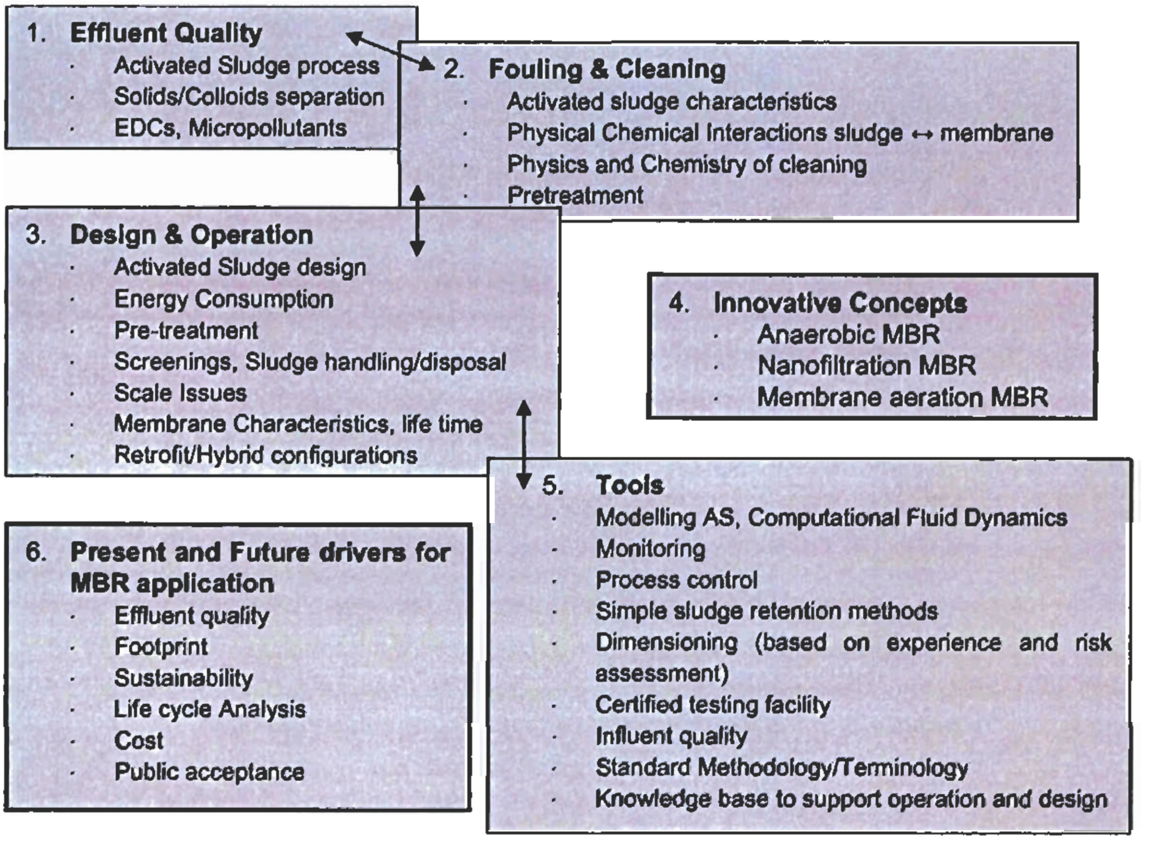
2.3.5 CONCLUDING REMARKS RESEARCH TOPICS STATE OF SCIENCE

The ranking of the research topics, as obtained by database analysis, literature review and questionnaire all result in the same topics for the first and second place: Membrane fouling and Effluent quality.
For the third place there is a difference between the results from the questionnaire and the other methods. The questionnaire came out with sludge treatment as the third important research topic. The others with energy/cost issues.
It can be remarked that depending on the region and the country, the ranking of these topics may differ.
Reduced footprint and superior effluent quality (enabling reuse) are the main drivers for application of MBR.

2.4 KNOWLEDGE MAP ON MBR

With the information of the state of the science report a knowledge map on MBR can be designed. This is done with a prioritised list, covering the relevant topics. This is done in six points (see Figure 2.1), each item is shortly characterised by relevant keywords and processes.

FIGURE 2.1 PRIORITISED RESEARCH TOPICS IN MBR, AS IDENTIFIED DURING THE WORKSHOP



3

RESEARCH STRATEGY

3.1 FROM KNOWLEDGE GAPS TO RESEARCH NEEDS

Based on the state of the science, the input of expert judgement and the workshop, knowledge gaps were identified which were translated to research needs to address these gaps. The major topics are:

- effluent quality: what is the objective performance of MBR and added value to existing technology;
- how to avoid and/or control membrane fouling;
- define the optimal design criteria and operational condition: what are the lessons to be learned from experiences worldwide?
- the development of tools to support the exchange of MBR knowledge and know-how and to answer the question "When, where and why to use MBR";
- what will be the role, benefits and limitations of MBR in future concepts for the urban water cycle and which technological innovations and developments can enhance future MBR applications.

Taking into account the ongoing research activities as part of the EU framework research program and within the GWRC membership, four of the identified research needs were processed to project proposals.

3.1.1 EFFLUENT QUALITY

There is some discussion about the role of humics and the extent to which they determine total phosphorus effluent concentrations. In a broader perspective it is until now unknown what the exact performance of an MBR is, with respect to the advanced removal of pathogens (especially viruses), organic and inorganic micro pollutants, EDC, pharmaceuticals and nutrients.

3.1.2 MEMBRANE FOULING & CLEANING

Membrane fouling and cleaning is identified as deserving careful attention of researchers in order to enable stable long-term operation. Several connected issues must be addressed:

- a more definite determination of the operating window for MBR. It is not yet clear whether we reached a border, or how far we are removed from the borders of 'good operation';
- configuration issues. What is the strength of hollow fibre system against plate and frame system? Or what is the advantage of one plate and frame system to the other?
- which influent characteristic(s) determine the applicability of MBR?
- which activated sludge characteristic(s) determine its filterability. In other words, with which parameters can the membrane filtration step be optimised?

These research topics are comprehensively covered within the European research proposals EUROMBRA and AMEDEUS.

3.1.3 TOOLS

KNOWLEDGE BASE

There is a need for a Knowledge Base on MBR practice. It should not be merely a database, but should enable its users to learn from success mistakes and failures of existing installations. The advantage of the knowledge base is that it has a larger life time than a 'normal' database, and that it can be updated once every two or three years, and not necessarily continuously. Furthermore it may promote further product development by manufacturers. Its primary users will be end users considering the design of an MBR.

DECISION SUPPORT TOOL

For a good comparison and assessment of different options, a decision support tool (DST) should be developed. The DST should comprise the following elements:

- effluent quality;
- footprint;
- investment/operational cost; whole life cost/ de-investment options;
- ease of operation;
- personnel;
- retro-fitting;
- life Cycle Analysis;
- reliability;

- size ranges;
- centralised/Decentralised system;
- public acceptance;
- upgradability/flexibility;
- residuals treatment: screenings, waste sludge, chemicals.

3.1.4 DESIGN/OPERATIONAL ISSUES

Pre-treatment was identified as the most important issue with regard to design/operation. There are some differences in approach when USA is compared to for example Europe, in the USA the pre-treatment is usually designed with characteristic size of 2-3 mm, whereas in Europe the common practice is less than 1 mm. This issue does not necessarily need scientific research, but careful attention in the design.

3.1.5 MODELLING/PROCESS CONTROL

This important issue is covered by the activities described under 3.1.3. and is also included in European research proposals as mentioned in 2.2.1.

3.1.6 INNOVATIVE CONCEPTS

Apart from being a one step process, MBR can also be regarded as part of a total water treatment system. Either in the form of hybrid configurations, or in combination with other techniques, many innovative concepts are thinkable. Some work has been done on Nanofiltration MBR. Other innovative ideas will have to be identified or maybe generated to expand the application field of MBR.

3.2 PROJECTS PROPOSED

The four selected research proposals are shortly described; the research proposal forms are included in Appendix V.

3.2.1 DECISION SUPPORT TOOL FOR MUNICIPAL MBR TECHNOLOGY CHOICE

MBR is an emerging new technology without clearly defined application boundaries compared with conventional technologies: MBR advantages are low footprint, disinfected and solids free effluent; disadvantages are energy requirement, cost, and process complexity. Up to date this technology choice for municipal applications was mainly driven by non-commercial considerations. No standard procedure for technology selection is currently available.
For an optimal use of the Knowledge Base and the Decision Support Tool there must be agreement on the use of terminology. A standardised set of terms and methods will have to be prepared. This will be part of the European projects.

3.2.2 DEVELOPMENT OF AN MBR KNOWLEDGE BASE FOR MUNICIPAL WASTEWATER TREATMENT

Due to its perceived advantages, within the past decade there have been many MBRs installed. Much of the information and lessons learned that was obtained with these installations has not been published or otherwise communicated. The web site database on MBR developed by WERF provides some information in this regard. However, detailed information that can be provided by global end users is not available. This type of information should be included in the knowledge base that will be developed.
The structure of the knowledge base of microfiltration installations, developed by AwwaRF, provides a good basis for further development. Ultimately, the information in the knowledge base can be used as input for newly to be developed Decision Support Tool.

3.2.3 EFFLUENT QUALITY OF MBRS

Claims on MBRs effluent quality are often overestimated. Facts are required for a rational comparison witb the conventional activated sludge process for the treatment of municipal wastewater. Clear data are required in terms of advanced removal of nutrients, disinfection (bacteria and viruses) and elimination of micro pollutants.

3.2.4 IDENTIFICATION OF INNOVATIVE CONCEPTS FOR FUTURE MBR SYSTEMS

MBR technology has almost reached maturity and the status of proven technology. Footprint reduction, disinfected effluent and overall stable effluent quality are among the main drivers for its current application level. Nevertheless, further development of the technology is still needed to expand the potential application of MBRs. In addition, the sanitation approacb is developing towards decentralised applications with closed loops of water, energy and nutrients recovery ("Ecosan concepts"). Novel MBR technologies may be very appropriate for the implementation of these new concepts or to improve the treatment performance of current MBR processes (e.g. trace organics), such as nanofiltration-MBR, anaerobic MBR, ceramic MBR, membrane aeration bioreactor, membrane biofilm reactor, etc.

4

CONCLUSIONS AND FOLLOW UP

One of the goals of the project was the exchange and review of existing knowledge and know-how within the GWRC membership and associated organisations. Based on the received feed-back it can be concluded that the combination of the International Symposium, the research strategy workshop as well as the field visit were very supportive to successfully achieve this goal.

Within this fruitful and constructive atmosphere the major knowledge gaps were identified and research needs to address the priority gaps were discussed.
As part of the developed research strategy four priority project proposals were agreed on:
- effluent quality of MBR (EAWAG);
- development of a MBR Knowledge Base for municipal wastewater treatment (STOWA);
- decision Support Tool for municipal MBR technology choices (KWB – AR);
- scenario study regarding MBR in 2030 (UKWIR).

With respect to the identified research needs on "Membrane Fouling and Cleaning" and "Issues regarding Modelling and process Control" the GWRC members that are participating in the EU projects will secure the exchange of information and overall co-ordination.

It was decided that for each of the project proposals one organisation (indicated in brackets above) would take the lead to elaborate in conjunction with the other workshop participants the proposals developed during the workshop.
The Board of the Directors of the GWRC will discuss and finally decide about the collaborative projects that will be executed within the framework of the MBR research strategy

APPENDIX I

AGENDA WORKSHOP MBR RESEARCH NEEDS

Global Water Research Coalition

Global Water Research Coalition

MBR Research Planning Workshop

The Netherlands
April 25-27, 2005

<u>PROGRAM (final)</u>

Global Water
Research Coalition

Participants

Adriano Joss	Swiss Federal Institute for Environmental Science and Technology	EAWAG	Switzerland
Boris Lesjean	KompetenzZentrum Wasser Berlin GmbH	KWB	Germany
Francis Luck	KompetenzZentrum Wasser Berlin GmbH	KWB	Germany
Pia Lipp	DVGW Water Technology Center	TZW	Germany
Sven Lyko	RWTH Aachen University, Dept. of Chemical Engineering	RWTH	Germany
Pete Pearce	Thames Water - UKWIR	Thames	UK
Eve Germain	Thames Water - UKWIR	Thames	UK
Samer Adham	MWH - Water Reuse Foundation	MWH	USA
Emile Cornelissen	Kiwa Water Research	KIWA	NL
Kees de Korte	Dienst Waterbeheer en Riolering Amsterdam	DWR	NL
Philip Schyns	Waterboard Rijn en IJssel	WRIJ	NL
Cora Uijterlinde	Foundation of Water Research	STOWA	NL
Frans Schulting	Global Water Research Coalition	GWRC	NL
Arjen van Nieuwenhuizen	Witteveen +Bos consulting engineers	W+B	NL
Herman Evenblij	Witteveen +Bos consulting engineers	W+B	NL
Peter de Jong	Witteveen +Bos consulting engineers	W+B	NL

stowa Waterschap Rijn en IJssel WATERBEHEER: VEILIG EN OP MAAT DHV

MBR-SYMPOSIUM: VARSSEVELD IN INTERNATIONAL PERSPECTIVE
Monday 25 April 2005; WWTP Varsseveld, Vlakkeeweg 9, 7051 GH Varsseveld

PROGRAM

9.00 Welcome reception/registration

9.30 Welcome and introduction by the chairman
drs. Cor Roos (Waterboard Rijn and IJssel)

9.45 MBR Varsseveld; Dutch demonstration of innovation
ir. Philip Schyns (Waterboard Rijn and IJssel)
ir. Helle van der Roest (DHV)

10.10 Experience with the MBR Technology at Erftverband [Erft Association] - from MBR Rödingen (3.000 p.e.) to MBR Nordkanal (80.000 p.e.)
dipl. ing. Norbert Engelhardt (Erftverband)

10.35 COFFEE AND TEABREAK

11.05 Japanese experiences with MBR in Waste Water Treatment
Dr. Takao Murakami (Japan Sewage Works Agency)

11.30 MBR in UK perspective
Pete Pearce (Thames Water)

11.55 LUNCH

13.10 MBR in perspective of the USA
Dr. Samer Adham (Montgomery Watson)

13.35 MBR Schilde up and running: 1,5 year of research and operational experience
ir. Wouter de Wilde (Aquafin)

14.00 COFFEE AND TEABREAK

14.30 Results of Dutch MBR research
ir. Cora Uijterlinde (STOWA, Foundation for applied Water Research)

14.55 ***Are we heading in the right direction?***
MBR - The state of the science anno 2005
dr.ir. Arjen van Nieuwenhuijzen (Witteveen + Bos)

15.20 Closing official program

nva Nederlandse Vereniging voor Waterbeheer Global Water Research Coalition Life

Global Water
Research Coalition

Tuesday, April 26 (Waterboard Rijn en Ijssel, Doetinchem)

STATE OF THE SCIENCE

9:00	Welcome Cora Uijterlinde, STOWA	
9:05	Overview of GWRC and its Methodology for Research Planning Description of Workshop Goals and Objectives Frans Schulting, GWRC	
9:15	Introduction workshop day 2 Workshop leader Peter de Jong, consultant	
9.45	Presentation of Literature Review - State of Science (2005) Herman Evenblij, consultant	
10.30	REFRESHMENT BREAK	
11.00	Overview and Status of MBR research of GWRC members (ongoing and planned research activities) ▪ KWB (representive AMEDEUS) - Boris Lesjean/Francis Luck ▪ TZW - Pia Lipp ▪ Kiwa - Emile Cornelissen ▪ EAWAG - Adriano Joss (representive EUROMBRA) ▪ US (WRF/WERF) – Samer Adham ▪ RWTH - Sven Lyko ▪ DWR – Kees de Korte ▪	
12:30	LUNCH	
13.30	Discussion Literature Review by GWRC members	
14.30	Departure to MBR Varsseveld	
15.00	Excursion to the MBR Varsseveld	Philip Schyns
16.30	Drive back to Arnhem	
19.00	Dinner	

Global Water
Research Coalition

Wednesday April 27 April (Villa Sonsbeek, Arnhem)

	KNOWLEDGE GAPS
9.00	Introduction workshop day 3 Arjen van Nieuwenhuijzen/Frans Schulting
9.10	Summarising Knowledge Gaps Arjen van Nieuwenhuijzen/Frans Schulting
	Group discussion • Knowledge Gaps, • Future Research Needs • Projects of Mutual Interest
10.30	REFRESHMENT BREAK
11.00	Priority Issues Future Research Needs
	Start with preparing project proposals (in breakout groups)
12:30	LUNCH
13.30	Writing project proposals
15.00	Presentation of project proposals
16.00	REFRESHMENT BREAK
16.30	Receive Final Input, Discuss Next Steps and Action Items
17.00	Workshop Summary & Closing Remarks Cora Uijterlinde and Frans Schulting
17.30	Adjourn - Dinner at your own

APPENDIX II

INTRODUCTION OF GWRC

Global Water Research Coalition

Workshop MBR

Varseveld, 25-27 April, 2005

Just to think about ....

- The ability to learn Dutch is closely related to the ability to cope with the pain felt when actually trying to speak it
- Goedemorgen => Good morning
- Liemersweg in Doetinchem => this place

Global Water Research Coalition

- Network organisation of water research organisations
- Water supply, sanitation, wastewater treatment and water reuse
- Motto:
  Global cooperation for the generation of water knowledge

Global Water Research Coalition

- Awwa Research Foundation initiative
- CRC WQT, UKWIR, TZW and WRC-SA support
- Fact founding mission in 2001
- Formal start in Melbourne on 10 April 2002
- Nieuwegein => 2005 - 2010

GWRC Objectives

- Exchange of information and knowledge
- Development of research strategies for global issues
- Coordination of joint research efforts
- Up to date Water Knowledge Database

GWRC Benefits

- Leverage for each organisation of expertise and funding
- Prevention of duplication and replication of research
- Different view angles and approaches!
- ***Knowledge Management on a global level***

The GWRC Founder Members

- Awwa RF
- WERF
- WRF
- Anjou Recherche (Veolia)
- CIRSEE (Suez)
- TZW
- EAWAG
- Kiwa
- STOWA
- UK WIR
- CRC WQT
- WSAA
- WRC – SA

- GWRC partner: US Environmental Protection Agency (July 2003)
  Centers for Disease Control and Prevention (2005)
- Urban water cycle (water supply, sanitation, wastewater treatment)
- Coordination of research programs at a (inter) national level

Way of Working

- Network Organisation
- Small staff – large resources

GWRC staff

Way of Working

- Network Organisation
- Small staff – large resources
- Contributions by the members
- IWA affiliate
  - support services
  - link with specialist groups
- Governance by Board of Directors

Board of Directors

Research Agenda

- Water Quality
  - Algal toxins
  - Origin and fate of water-borne pathogens
- Emerging Hazards (EDC, PhAC, NDMA, ...)
- Water Quality in Distribution Systems
- Asset Management
- Membrane Filtration – Drinking Water
- **Wastewater Treatment - MBR**
- Water Reuse
- Water Concepts of the Future

Research Activities

- GWRC research agenda based on members needs
- **Research strategy for priority issues**
  - **Review of existing knowledge and activities**
  - **Workshop about knowledge gaps and research needs => map of knowledge**
  - **Portfolio of research projects**
- Tailor made project teams with one member as lead agent
- Sharing the results within the GWRC
- Knowledge transfer to stakeholders by the members

WWT - Membrane Bioreactors

- Lead Agent: STOWA
- Participating members: EAWAG, Kiwa, TZW, UKWIR, WRF/WERF and WKB (Anjou)
- Remote input: CRC WQT and WRC-SA

Membrane Bioreactors – Wastewater Treatment

- Background documents
  - Survey of members activities (February-March 2005)
  - State of the Science (STOWA draft April 2005)
- Workshop MBR (April 2005)
  - Exchange of Knowledge
  - Identify knowledge gaps and research needs
  - Project proposals of joint activities
- Follow up
  - Workshop report
  - Research strategy and priority projects => Board

Workshop MBR

- Day 1 – Exchange of knowledge
  - Regional perspectives
  - Dutch experience – Varseveld
- Day 2 – Knowledge gaps and research needs
  - State of the Science
  - Views of the GWRC members
  - Selection of priority issues
  - Field visit
  - AC Milan – PSV Eindhoven
- Day 3 – Project Proposals
  - Development of project proposals
  - Follow up, actions and assignments

Global Water Research Coalition

Sharing the power of knowledge!

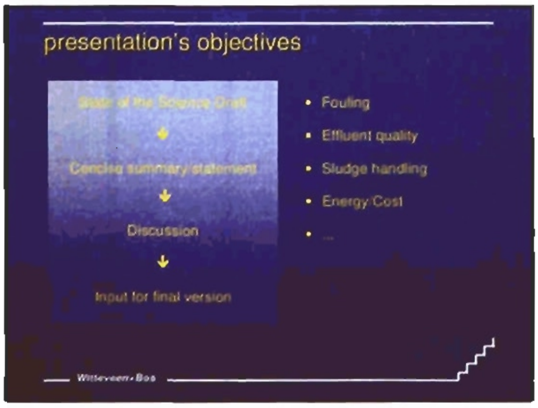
Global Water Research Coalition

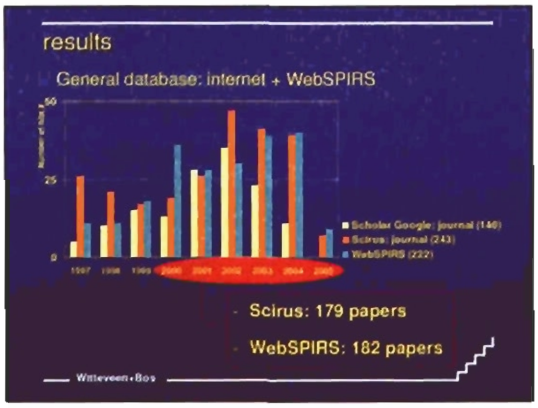
www.globalwaterresearchcoalition.net

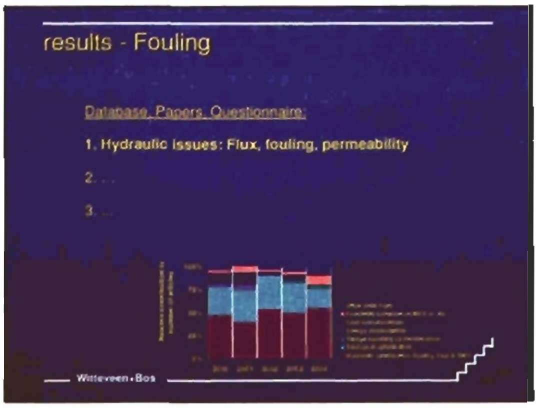
APPENDIX III

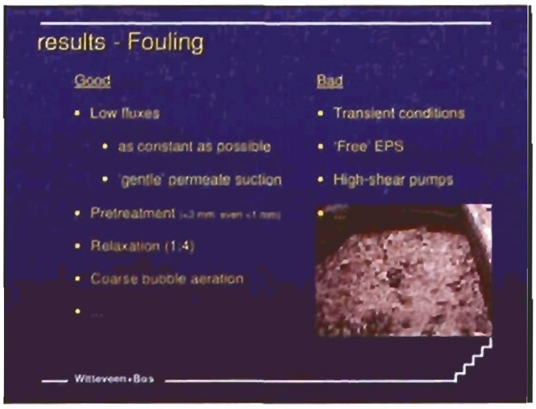
PRESENTATION DRAFT STATE OF SCIENCE REPORT

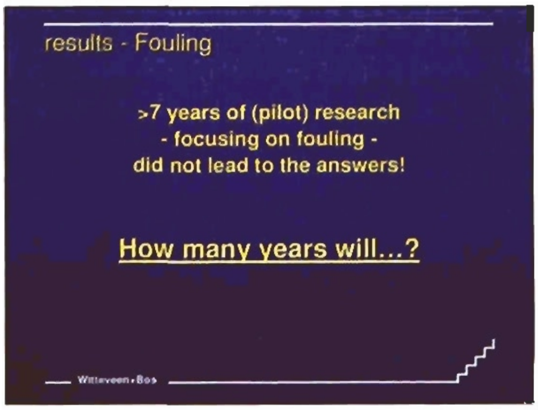

stowa
Global Water Research Coalition
Witteveen Bos
MBR - State of the Science
anno 2005
Workshop MBR Research Needs
April 26-27, 2005 - Doetinchem/Arnhem - The Netherlands
Witteveen+Bos Consulting Engineers

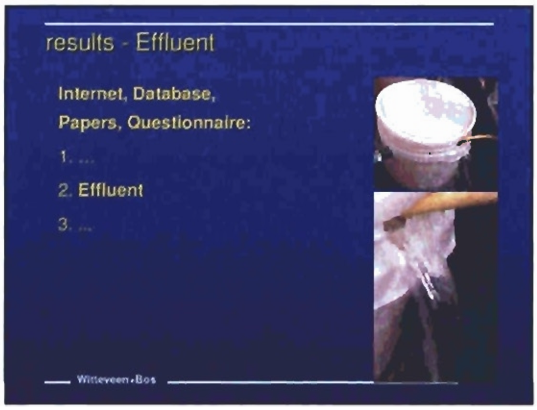

presentation's objectives
Concise summary/statement
Discussion
Input for final version
Fouling
Effluent quality
Sludge handling
Energy/Cost
...
Witteveen+Bos

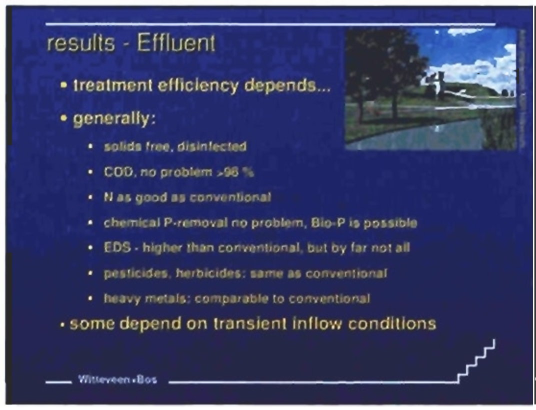

results
General database: internet + WebSPIRS
50
25
0
Scholar Google: journal (140)
Scirus: journal (243)
WebSPIRS (222)
Scirus: 179 papers
WebSPIRS: 182 papers
Witteveen+Bos

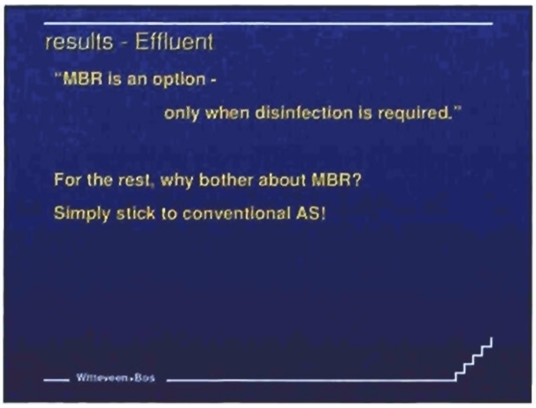

results - Fouling
Database, Papers, Questionnaire:
1. Hydraulic issues: Flux, fouling, permeability
2. ...
3. ...
Witteveen+Bos

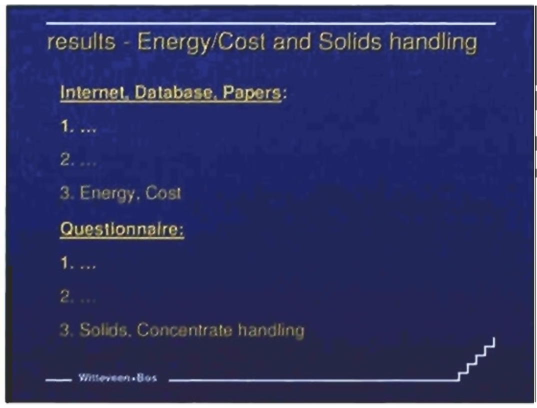

results - Fouling
Good
Low fluxes
as constant as possible
'gentle' permeate suction
Pretreatment
Relaxation (1:4)
Coarse bubble aeration
...
Bad
Transient conditions
'Free' EPS
High-shear pumps
Witteveen+Bos

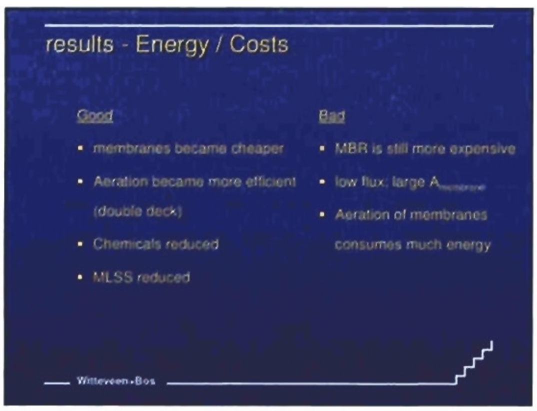

results - Fouling
>7 years of (pilot) research
- focusing on fouling -
did not lead to the answers!
How many years will...?
Witteveen+Bos

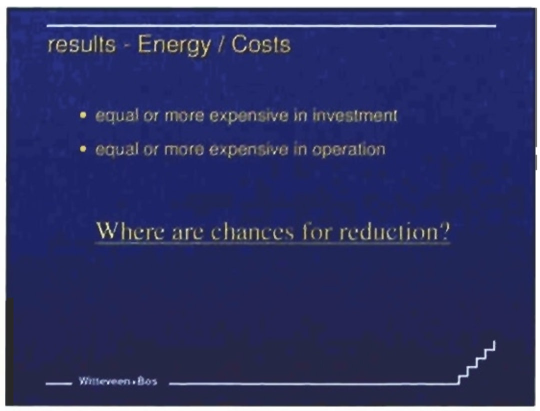

results - Effluent
Internet, Database,
Papers, Questionnaire:
1. ...
2. Effluent
3. ...
Witteveen+Bos


results - Effluent
• treatment efficiency depends...
• generally:
• solids free, disinfected
• COD, no problem >96 %
• N as good as conventional
• chemical P-removal no problem, Bio-P is possible
• EDS - higher than conventional, but by far not all
• pesticides, herbicides: same as conventional
• heavy metals: comparable to conventional
• some depend on transient inflow conditions
Witteveen+Bos

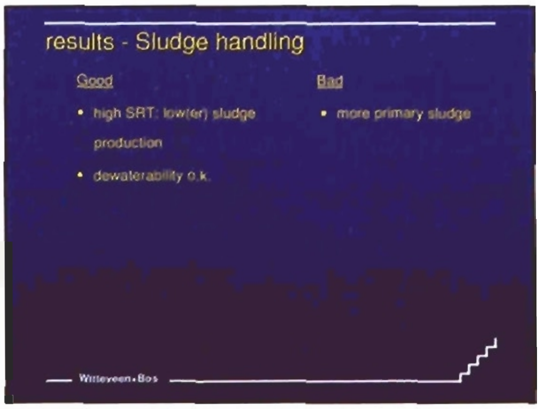

results - Effluent
"MBR is an option -
only when disinfection is required."
For the rest, why bother about MBR?
Simply stick to conventional AS!
Witteveen+Bos

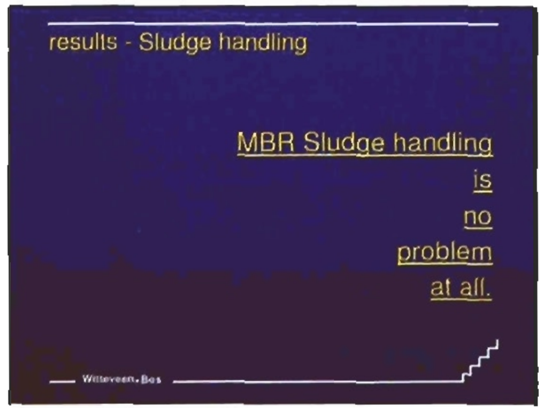

results - Energy/Cost and Solids handling
Internet, Database, Papers:
1. ...
2. ...
3. Energy, Cost
Questionnaire:
1. ...
2. ...
3. Solids, Concentrate handling
Witteveen+Bos

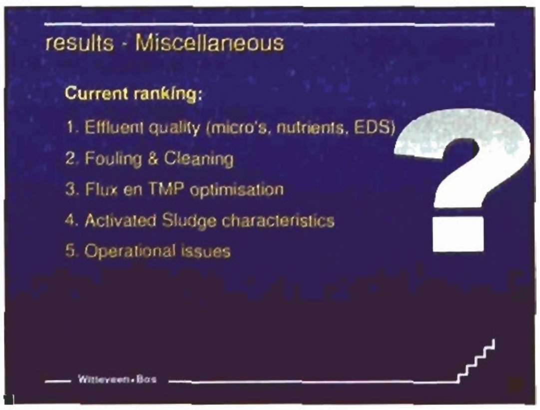

results - Energy / Costs
Good
• membranes became cheaper
• Aeration became more efficient (double deck)
• Chemicals reduced
• MLSS reduced
Bad
• MBR is still more expensive
• low flux; large A
• Aeration of membranes consumes much energy
Witteveen+Bos


results - Energy / Costs
• equal or more expensive in investment
• equal or more expensive in operation
Where are chances for reduction?
Witteveen+Bos

2


results - Sludge handling
Good
high SRT: low(er) sludge production
dewaterability o.k.
Bad
more primary sludge
Witteveen+Bos


results - Sludge handling
MBR Sludge handling
is
no
problem
at all.
Witteveen+Bos


results - Miscellaneous
Current ranking:
1. Effluent quality (micro's, nutrients, EDS)
2. Fouling & Cleaning
3. Flux en TMP optimisation
4. Activated Sludge characteristics
5. Operational issues
Witteveen+Bos


stowa
Global Water Research Coalition
Witteveen
Bos
MBR - State of the Science
anno 2005
Thank
you!!
Workshop MBR Research Needs
April 26-27, 2005, Doetinchem/Arnhem, The Netherlands

APPENDIX IV

PRESENTATIONS OF RESEARCH ACTIVITIES BY WORKSHOP PARTICIPANTS

- RESEARCH CONSORTIA EUROMBRA/AMEDEUS (EU)
- TZW/DVGW (D)
- UKWIR/THAMES WATER (UK)
- WRF/WERF (USA)

Global Water Research Coalition Workshop
26-27 April 2005

Introducing the two new coordinated EU projects on MBR R&D

AMEDEUS
Accelerate Membrane Development for Urban Sewage Purification

EUROMBRA
Membrane bioreactor technology with an EU perspective for advanced municipal wastewater treatment strategies for the 21st century

3rd Call of the 6th Framework Programme
Priority Global Changes and Sustainable Development

KOMPETENZZENTRUM Wasser Berlin

Facts

- Call dedicated to MBR development for municipal applications
- Aim to foster MBR technology advances, competitiveness, acceptance and application in EU
- All sizes (decentralised to large scale) + new plants / refurbishing
- Fundamental + applied R&D
- Cluster of 28 European and international partners
- 3 year R&D Projects, to be started in October 2005
- Budget of ca. € 10 million, incl. € 6 million contribution

Strategic objectives

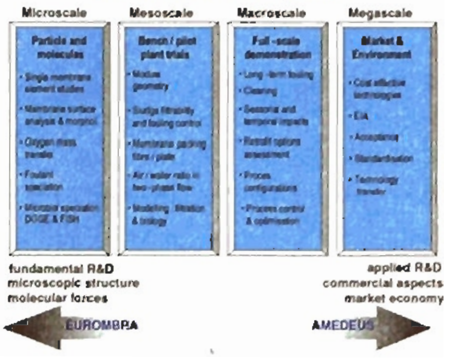
Develop **sustainable solutions** for new, efficient and cost-effective **advanced wastewater treatment technologies** for municipal wastewater based on membrane bioreactor technology.

- Industrial: Foster development of competitive European MBR-filtration technologies to secure MBR market shares
- Technological: Increase competitiveness and reliability of MBR techniques in comparison with conventional processes
- Environmental: Broaden a high-tech process to common practice in environmental engineering

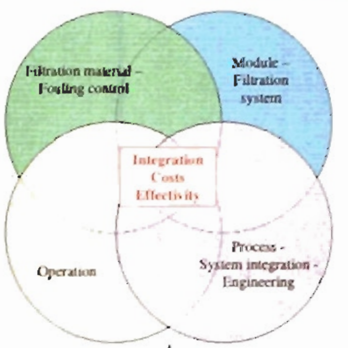
The two consortia

	AMEDEUS	EUROMBRA
Universities	TU Berlin, Germany UNSW, Sydney, Australia	**NTNU, Trondheim, Norway** Cranfield Uni, UK RWTH Aachen, Germany IBET Lisboa, Portugal INSA Toulouse, France Uni Montpellier II, France TU Delft, Netherlands Uni Trento, Italy Uni Kwazulu-Natal, Durban
R&D centers	**KWB, Berlin, Germany** VITO, Belgium Tecnoservizio, Italy	Uni Tech, Sydney, Australia UNESCO-IHE, Netherlands EAWAG, Switzerland
End-Users	Anjou Recherche / Veolia, France Aquafin, Belgium	WHD, Netherlands Erftverband, Germany
SMEs	Polymem, France Millenniumpore, UK A3, Germany Inge, Germany Euro Pure, Czech Republic	Polymem, France Millenniumpore, UK Puron, Germany FlowConcept, Germany

The scales of investigation



Acting on all fields of MBR processes



Fouling and membrane interaction

- Membrane / fouling characterisation methods
- Qualitative and quantitative analysis of foulants (short and long term)
- Interaction between foulants and membranes, impact of identified foulants in practice
- Impact of biological operational parameters, flux, aeration etc
- Impact of dynamic effects: hydraulic and organic load variation
- Impacts of and on microbial speciation and diversity
- Modification of membrane composition, structure and surface

Optimisation of cleaning protocols

- Maintenance vs. curative cleaning (cleaning-in-place)
- Reduced chemical consumptions, costs & handling
- "On-air" cleaning? (also for flat-sheet membranes)
- Alternatives to chlorine? Oxidants or anti-scaling products?
- Impact on membrane life-time, accelerating aging tests

Non-invasive, on-line monitoring of foulants

- Biological, physical or chemical sensors
- Diverse degrees of sophistication:
  - Automised MFI on sludge or sludge filtrate
  - Single-filament or other dedicated test cells as indicator of sludge fouling propensity
  - Photometric measurement with Flow Injection Analysis
  - FISH probes to characterise biology and population dynamics
  - Bi-dimensional fluorometry and Denaturing Gradient Gel Electrophoresis (DGGE)

Module geometry and aeration

- Bi-phasic CFD model for optimisation of modules and filtration reactors
- Impact of module geometry on short and long term fouling behavior and filtration performance
- Impact of flow pattern and aeration mode on performances
- Enhanced mass transfer characteristics

Concentrate / sludge handling

- Sludge production
- Sludge characterisation and dewaterability
- Adapted sludge treatment
- Impact of extra-cellular polymeric substances
- Sludge stabilisation

Process modelling

- For improvement of design and operation:
  - Nutrients removal
  - Sludge production
  - Filtration modeling
  - Fouling prediction
  - Dynamic modelling (hydraulic and pollutant loads)
  - Biological models coupled with hydrodynamic models (CFD and residence time distribution)

Towards tomorrow's European MBR technologies

- 5 membrane / module producers
  - A3 (FM)
  - Puron (HF)
  - Polymem (HF)
  - Milleniumpore (Tub)
  - Inge (multi-channel)

  … each of them developing a specific concept of MBR system, ultimately adapted to different sizes and conditions
- a textile research centre
  - Tecnotessile
- a constructor of small turn-key plants
  - Envi-Pur

Fouling control through additives

- Assumptions: organic fouling occurs through colloids with « impredictable » occurrence

  => Additives for physical-chemical removal (flocculents, adsorbents, enzymes, etc)
- Strategies of fouling control & flux enhancement with chemical addition with on-line organic foulant sensors
  - Daily peaks
  - Rain events
  - Seasonal peaks
- "Compact MBR": low SRT / low HRT + on-line fouling control

Optimisation of process configurations

- MBR with or without primary sedimentation?
- Submerged modules externally or directly in aerated reactor?
- Dual MBR/CAS for plant retrofitting?
- Turn-key standardised range of MBR/filtration units?
- How to best tackle peaks? (biology & filtration)
- Integrated hydrodynamics of membrane / biological system?
- Models as predicting tools + pilot- & large-scale validation

Process control

- Advanced data acquisition, supervision and control system for MBR
  - Remote advanced control system for small MBR plants (operation diagnostics and alerts)
  - Automatisation of reportings and maintenance planning
  - Dynamic filtration control for larger plants ("fuzzy-logic" approach)
- Optimised control strategy of influent split for MBR/CAS in parallel

European standardisation / normalisation of MBR technology

Analysis of economical interest and technical practicability

- Existing commercial technologies + novel technologies
- Standardisation of membrane / fouling /aging characterisation methods

=> « White-paper » for EU-Commission and tenders in Europe
+ initiation of EU-wide standardisation activity
(in liaison with Committee 165 of CEN + a national standard Assoc.)

Clustering activities

- Programme & results integration between two projects
- Overall cost benefits analysis
- Dissemination
- Technology transfer workshops and project presentations
- Web-platform dedicated to MBR community
  - Updates on both projects
  - Discussion forum
  - Event data base
  - Data base of international stakeholders
  - Data base of literature

DVGW: German Technical and Scientific Association for Gas and Water

- Founded in 1859 as an independent, non-profit technical-scientific association
- Mission: advance the gas and water industry in both the technical and technical-scientific context
- Members:
  - 1,646 gas and water utilities
  - 227 public authorities and organizations
  - 1,293 companies
  - 8,697 individual members

DVGW - Areas of Work

- Regulation and Standardisation (technical rules, cooperation with DIN)
- Testing and Certification (CE-Number, DIN-DVGW-certificate, DVGW-certificate, DVGW-quality mark, DVGW-approved company, DVGW-management systems, DVGW-experts)
- Research and Development
- Training
  - DVGW-Forum: Nationwide events up-to-date information
  - DVGW-Job-training: Job and further training
  - DVGW-Regional: Events organized by the DVGW-regional groups
- Information and Know-how transfer
- TZW - part of the DVGW
  Center for applied water research

Water Technology Center (TZW)

- Independent, non-profit organization
- Mission:
  Transferring science to the water industry
- Branches in Dresden and Hamburg
- Financial background
  - 35 % research projects by government, DVGW, EU
  - 65 % joint research projects with waterworks (development of new technologies, new analytical methods, technical rules - no consultant)

Working Fields of the Water Technology Center

- Analytical Chemistry
- Technology
- Microbiology
- Environmental Biotechnology and Site Management
- Groundwater and Soil
- Corrosion
- Material Testing

Analytical Chemistry

Fate-studies for organic micropollutants

- Lab-scale tests for simulation the microbial degradation at environmental concentration levels
- Lab-scale experiments to study the behavior of inorganic and organic compounds during oxidation processes (ozonation, AOP)
- Lab-scale UV irradiation experiments
- Lab-scale experiments for the assessment of the absorption capability of organic compounds on activated carbon
- Formation of oxidation or disinfection by-products during water treatment processes
- Column elution tests for the determination of the release of organic pollutants from waste materials

Analytical Chemistry
Research & Development

- Development and optimisation of analytical methods for the determination of organic micropollutants in water (drug residues, x-ray contrast media, steroidal hormones, aromatic sulfonates, synthetic complexing agents, aliphatic amines, ...)
- Methods for the analysis of pesticides and their metabolites
- Occurrence, analysis and assessment of drug residues and endocrine disrupting chemicals (EDC) in the water cycle
- Development and testing of on-line techniques for the analysis of organic micropollutants
- Comparison of field-based and laboratory-based experiments for the study of the elimination efficiency of riverbank filtration processes under different environmental conditions
- Literature surveys on chemical compounds (aromatic sulfonates, synthetic complexing agents,...)

Technology

Research projects - Membranes (I)

- Assessment of novel UF and MF membranes for drinking water treatment from surface waters
- Objective:
  Examination of backwashable spiral wound membrane elements
- Funding:
  German Ministry of Education and Research

Technology

Research projects - Membranes (II)

- Long term behavior of ultrafiltration membranes
- Objective:
  Optimization of backwash process to extend membrane life
- Funding:
  German Gas and Waterworks Association

Technology

Research projects - Membranes (III)

- Test methods to determine the performance of membranes in laboratory scale
- Objective:
  Scientific tool for choice of membranes for special applications
- Funding:
  German Gas and Waterworks Association

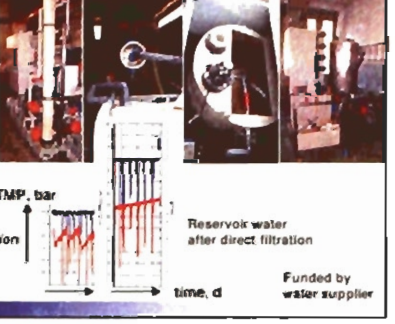
Technology

Research projects - Membranes (IV)

- Removal of algae with membranes without toxin release
- Objective:
  Determination of suitable membrane systems and optimal operation conditions
- Funding:
  German Ministry of Education and Research

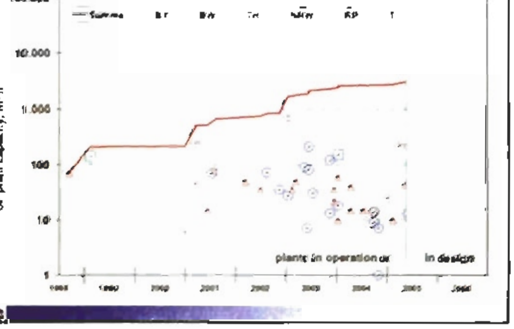
Technology

Pilot trial with different UF-systems to decide on the type of pretreatment



Funded by water supplier

UF-plants for public drinking water supply



Summary

- TZW (centre for water technology) is mainly involved in drinking water treatment concerning treatment technologies.
- My main working area is membrane technology (MF, UF, NF, RO) in water treatment since 20 years.
- TZW operates membrane systems in pilot scale mainly for drinking water treatment (also filter backwash water) not yet MBR or municipal waste water
- TZW is involved in waste water projects through its analytical capacity.

MBR Research needs

- MBR will be further implemented in municipal waste water treatment because of stronger requirements for the discharge with regard to effluent quality.
- MBR will be an alternative for increasing capacity of existing conventional wastewater treatment plants because of the smaller footprint and better quality although operational costs will be higher.
- The research need will be to develop better membranes which show less fouling, need less aeration and therefore need less energy.
- Another objective of research may be the decomposition of organic micropollutants within the MBR process.
- In Germany there is a thinking about treating special waste streams at the point of occurrence (e.g. hospitals)
- Research studies in lab-scale and pilot-scale should investigate the performance and limits.

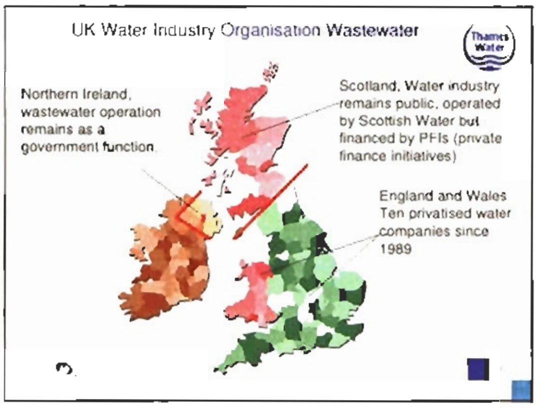
Membrane Bioreactors A UK perspective

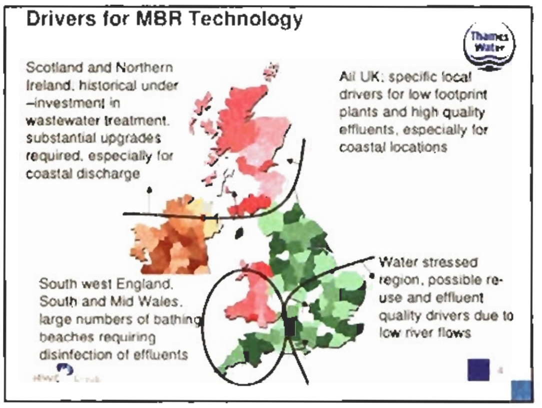
Pete Pearce

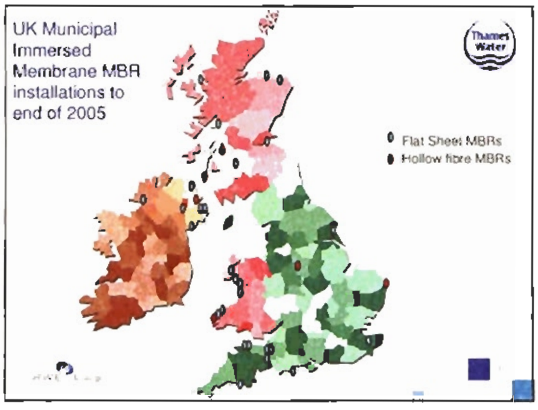
Research and Development
Thames Water Utilities Ltd

Presenters Perspective

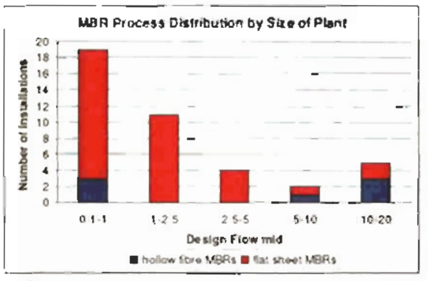
- Thames Water utilities does not operate any MBRs
- Recently completed a four year research programme, looking at control of short term fouling on hollow fibre membranes (Zenon) by studying biological (biomass) and physical (aeration) effects
- AWM, a Thames Water Subsidiary company operate around 20 MBRs in the North East USA. Several of these are 10 – 12 years old and represent some of the original Zenon designs
- The operation of these plants have been studied in some detail



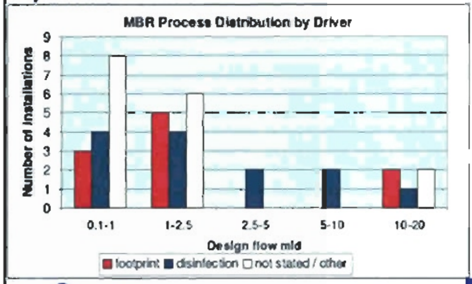




UK Municipal MBR Installations to end of 2005



UK municipal MBR installations, process drivers



RWE Group 7

MBR development in UK

- 1995 – Wessex Water tie up with Kubota to investigate use of Kubotas flat sheet MBR system
- 1998 First Kubota system commissioned at Porlock STW (2 mld)
- 2000 First larger Kubota system commissioned at Swanage (13 mld)
- 2000-2005 29 further Kubota systems installed
- 2000 – 2005 fewer Zenon plants installed but tend to be larger plants. Largest operated by Severn Trent Water at Buxton treats a maximum flow of 17 mld was commissioned in 2004
- Now four suppliers of MBRs. Zenon, Kubota (via COPA MBR), Toray (2 plants installed to date (Via Nastons) and Mitsubishi Rayon

RWE Group 8

Main UK Research Centres For MBRs

- Cranfield University – Hosts biennial MBR conference, started with MBR1 in 1995 Applications, fouling, aeration.
- Bath University – fouling, cleaning, surface interactions
- Imperial College – anaerobic gas sparged MBR systems
- Several Water PLCs have conducted own pilot trials with hollow fibre and flat sheet systems, 8 out of 10 now operate at least 1 MBR plant

RWE Group 9

Operational Problems and Research Requirements

- Foaming due to load variations on small plants and poor control of biological process
- Foaming and loss of flux due to saline ingress on coastal sites
- Fouling/clogging due to inadequate screening
- High maintenance requirements, ease of membrane removal/handling
- Further optimisation of membrane aeration to reduce operational cost
- Further optimisation of short and long term fouling control to reduce operational cost (manpower)
- Improved design of membrane modules/materials to permit higher flux to reduce capital cost
- Improved understanding of biological interactions to reduce fouling/foaming

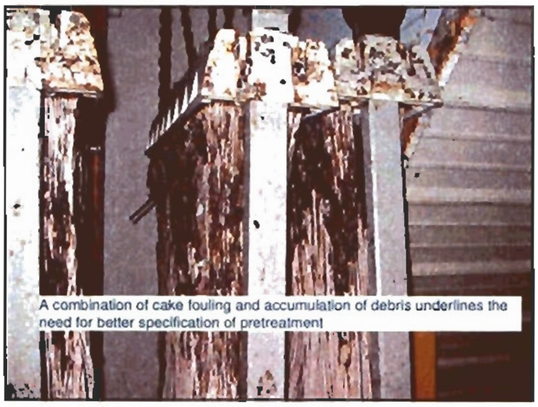
RWE Group 10

Future Drivers

- Footprint – especially at coastal locations with low land availability due to amenity and lack of prior treatment facilities. Also for compact plant to allow enclosure to reduce nuisance.
- Disinfection – especially at coastal locations discharging to bathing waters. Often more cost effective than construction of long outfalls
- High quality effluents - For stringent discharge requirements to high quality surface water or for groundwater recharge.
- EDC removal? Yet to be studied in depth. Our own initial findings are that MBRs give improved EDC removal though still insufficient to meet proposed targets for natural steroid oestrogens
- Re use? Proposals for community re-use have been raised in South East region but none have yet been adopted. Pressure to do so is likely to increase as further growth is targeted in the driest regions of the UK

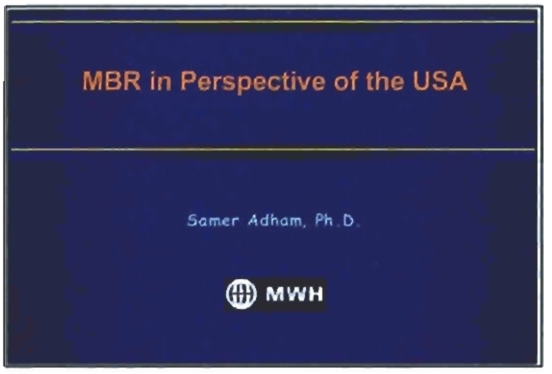
RWE Group 11

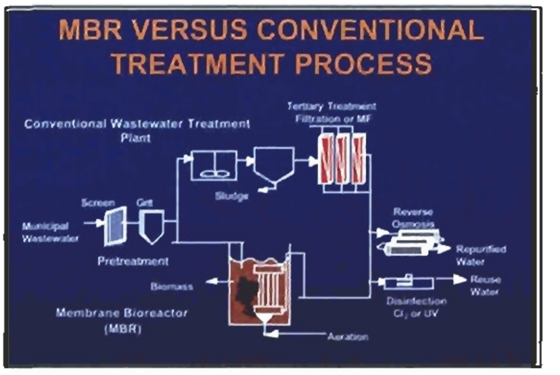
MBRs offer the possibility of hiding sewage treatment works – A small community recycling plant in New England

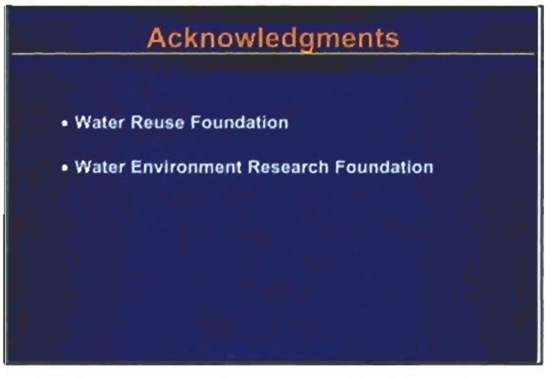

A combination of cake fouling and accumulation of debris underlines the need for better specification of pretreatment

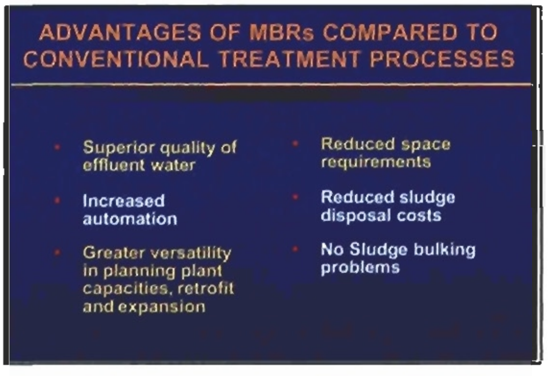

These membranes barely made their 5 year guarantee, How much of this was due to poor pre treatment? How can membrane life be extended?


Designs Have Changed substantially since these first Zenon installations from the early 1990's, underlining the need for ongoing research and development

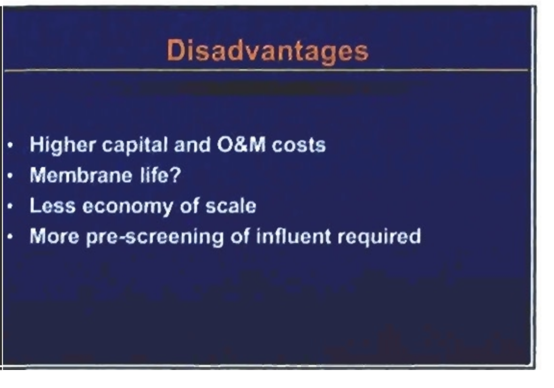

MBR in Perspective of the USA
Samer Adham, Ph.D.
MWH


MBR VERSUS CONVENTIONAL TREATMENT PROCESS
Conventional Wastewater Treatment Plant
Tertiary Treatment Filtration or MF
Sludge
Screen
Grit
Municipal Wastewater
Pretreatment
Reverse Osmosis
Repurified Water
Biomass
Reuse Water
Disinfection Cl₂ or UV
Membrane Bioreactor (MBR)
Aeration

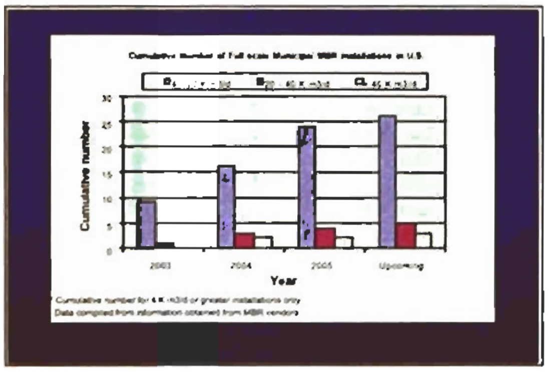

Acknowledgments
• Water Reuse Foundation
• Water Environment Research Foundation

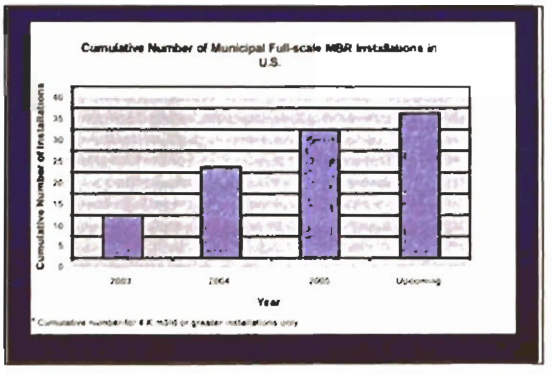

ADVANTAGES OF MBRs COMPARED TO CONVENTIONAL TREATMENT PROCESSES
• Superior quality of effluent water
• Increased automation
• Greater versatility in planning plant capacities, retrofit and expansion
• Reduced space requirements
• Reduced sludge disposal costs
• No Sludge bulking problems

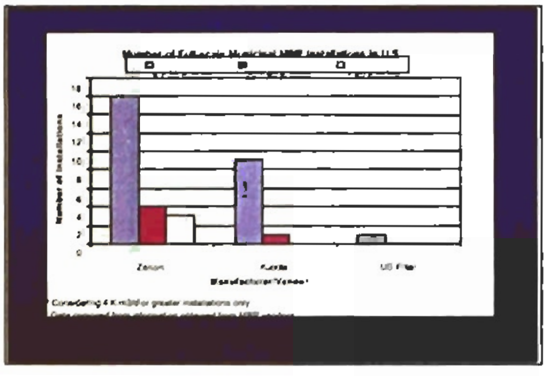

Outline of Presentation
• Background
• MBR Installations in US
• Past and Current MBR Research in US
• MBR Research Needs

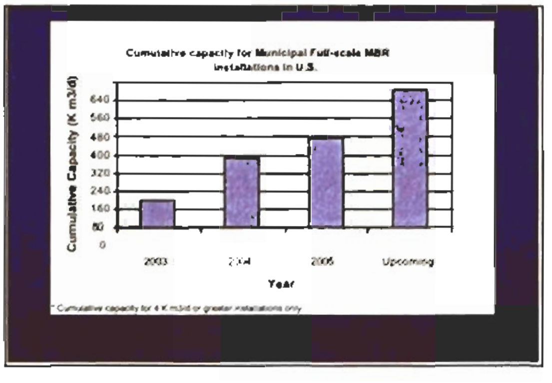

Disadvantages
• Higher capital and O&M costs
• Membrane life?
• Less economy of scale
• More pre-screening of influent required

MBR Installations in the US



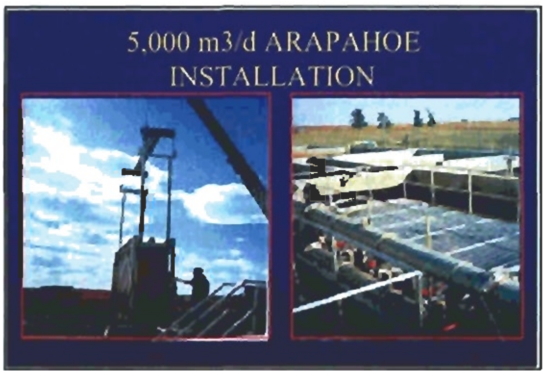


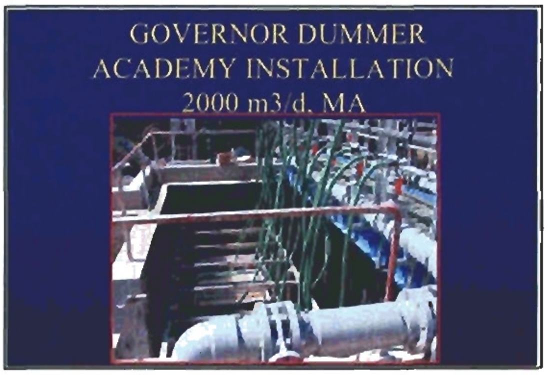


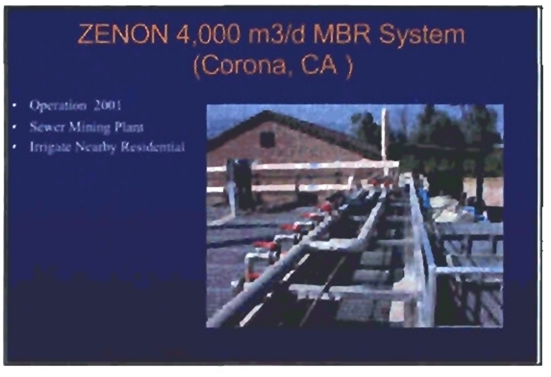


Largest MBR Installations in US

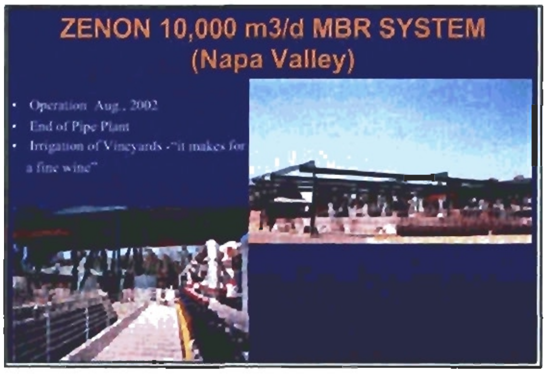
- 40,000 - 60,000 m3/d Traverse City, MI
- 25,000 - 60,000 m3/d Fulton County, GA
- 130,000 m3/d King County, WA (planned 2010)


5,000 m3/d ARAPAHOE
INSTALLATION


GOVERNOR DUMMER
ACADEMY INSTALLATION
2000 m3/d, MA


ZENON 4,000 m3/d MBR System
(Corona, CA)
• Operation 2001
• Sewer Mining Plant
• Irrigate Nearby Residential


Current Status of MBR
Research in US


ZENON 10,000 m3/d MBR SYSTEM
(Napa Valley)
• Operation Aug., 2002
• End of Pipe Plant
• Irrigation of Vineyards -"it makes for a fine wine"

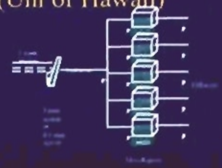

MBR Research Funding
Organizations in US
• Water Reuse Foundation (WRF)
• Water Environment Research Foundation (WERF)
• Bureau of Reclamation (B of R)
• National Water Research Institute (NWRI)
• American Water Works Research Foundation (AwwaRF)

WRF

WERF

Honolulu MBR Pilot Study (Ongoing)
Dr Roger Babcock (Uni of Hawaii)

- Side-by-side pilot demonstration
- Five leading manufacturers
- Three waste streams
- Comprehensive analytical testing
- Engineering and operation/maintenance analyses



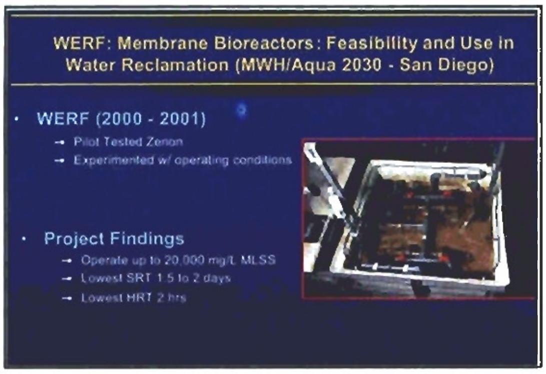
WERF Projects

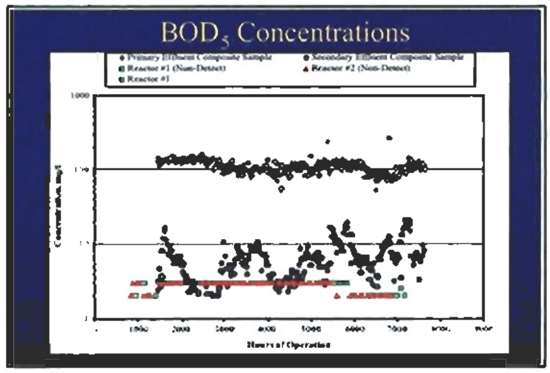
- Membrane Bioreactors: Feasibility and Use in Water Reclamation
- Membrane Technology: An Innovative Alternative in WW Treatment
- A Novel Membrane Process for Autotrophic Denitrification
- Membrane Technology: Feasibility of Solid/Liquid Seperation in WW treatment
- Effects of Biosolids Properties on MBRs and Solid Processing

Honouliuli Wastewater Plant: Pilot Test Site

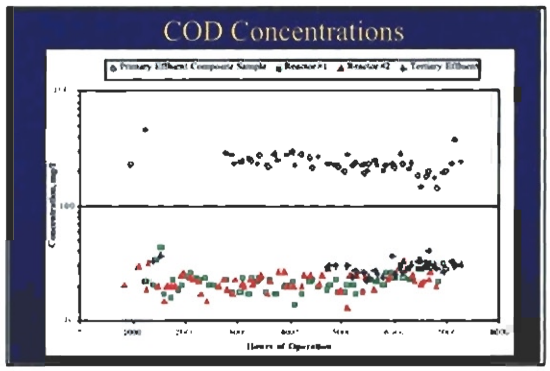
WERF Projects (cont.)

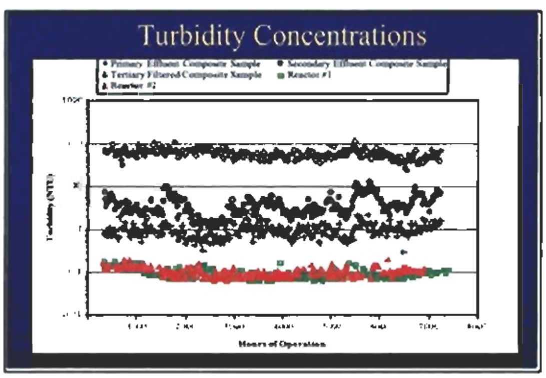
- Membrane Technology: Pilot Studies of Membrane-Aerated Bioreactors
- Membrane Treatment of Secondary WW effluents for Subsequent Use
- Membrane Bioreactors for Anaerobic Treatment of Wastewaters

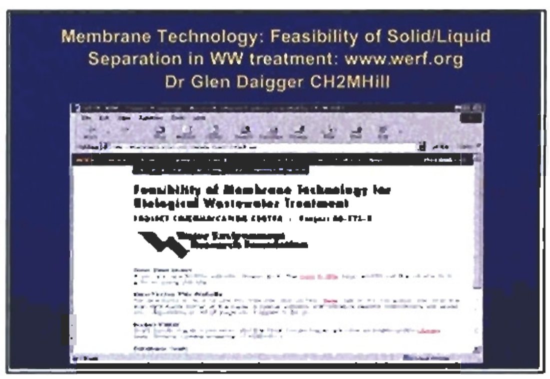

WERF: Membrane Bioreactors: Feasibility and Use in Water Reclamation (MWH/Aqua 2030 - San Diego)
• WERF (2000 - 2001)
→ Pilot Tested Zenon
→ Experimented w/ operating conditions
• Project Findings
→ Operate up to 20,000 mg/L MLSS
→ Lowest SRT 1.5 to 2 days
→ Lowest HRT 2 hrs

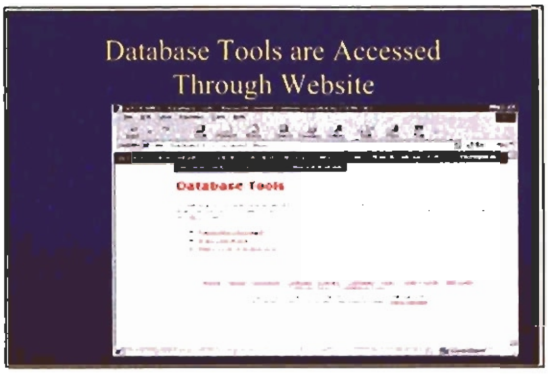

BOD5 Concentrations
Primary Effluent Composite Sample
Secondary Effluent Composite Sample
Reactor #1 (Non-Detect)
Reactor #2 (Non-Detect)
Reactor #1
Concentration, mg/l
Hours of Operation


MBR Pilot Units

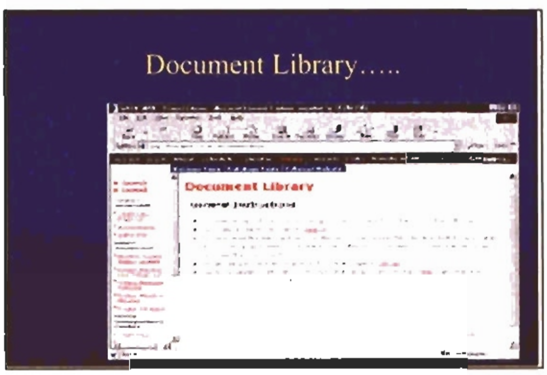

COD Concentrations
Primary Effluent Composite Sample
Reactor #1
Reactor #2
Tertiary Effluent
Concentration, mg/l
Hours of Operation

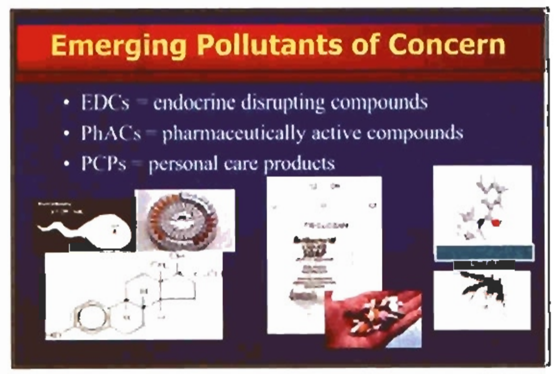

Turbidity Concentrations
Primary Effluent Composite Sample
Secondary Effluent Composite Sample
Tertiary Filtered Composite Sample
Reactor #1
Reactor #2
Turbidity (NTU)
Hours of Operation


Membrane Technology: Feasibility of Solid/Liquid Separation in WW treatment: www.werf.org
Dr Glen Daigger CH2MHill
Feasibility of Membrane Technology for Biological Wastewater Treatment

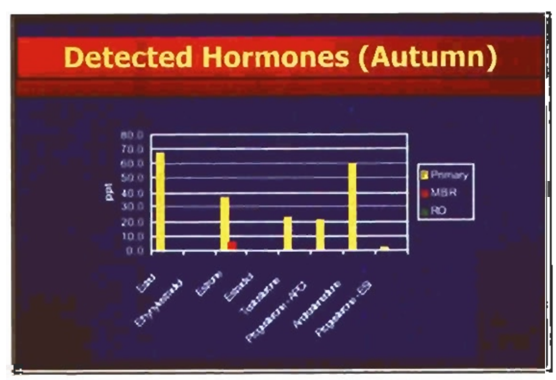

Database Tools are Accessed
Through Website
Database Tools


MBR Research Program
(MWH-Aqua 2030)
Bureau of Reclamation (1997 - 2004)
Phase I Literature Review / Survey
Phase II Pilot Testing Zenon & Mitsubishi
Phase III Pilot Testing of four MBR vendors
Project Findings
Phase I - Benefits, types, manufacturers, operating conditions, full scale operations
Phase II - Excellent water quality, reasonable cleaning intervals, permeate suitable for RO feed, peaking feasible
Phase III - Variable operational performance among MBRs, can be operated on advanced primary effluent, EDC removal, cost effective

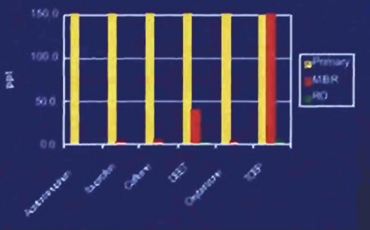

Document Library.....
Document Library


Emerging Pollutants of Concern
EDCs = endocrine disrupting compounds
PhACs = pharmaceutically active compounds
PCPs = personal care products


B of R


Detected Hormones (Autumn)
ppt
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Primary
MBR
RO

Detected Personal Care Products (Autumn)



Summary

- MBRs are gaining momentum in the US with over 35 installations in municipal sector
- Small footprint, effluent quality, and ability to retrofit existing WW treatment plants are key drivers
- Significant research has and continues to be done in the US on MBR process evaluation and optimization. More globally coordinated research is still needed to enhance the feasibility of the technology.

Research Needs

WRF MBR Research Need

- Improving the Economics and Reliability of MBRs for Municipal WW Treatment and Reuse.
- Membrane Fouling: Causes and Solutions.
- Decision Support Systems for Satellite vs Regional Treatment for Reuse Systems.
- Develop Large-Scale/Pilot Level Demo "Platform" for Testing Emerging Technologies.
- Development of Fouling Resistant Membrane for Cost Effective and Selective Removal of EDC/PACs from WW.

Research Needs

- Fouling Mechanisms and Control.
- Optimize MBR for high-level Phosphorous removal
- Evaluate anaerobic MBR systems
- Evaluate unique advantages of new MBR suppliers
- Optimization of MBR for EDC/PPCPs removal
- Evaluate the feasibility of using NF in MBRs

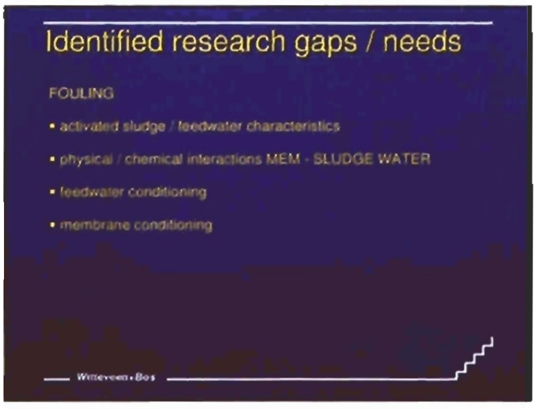
WERF MBR Research Needs

- Fouling Mechanisms and Control.
- Characterization of Microbiology and Impact of Operating Parameters on Membrane System Performance.
- Design and Operational Parameters for Membrane Optimization.
- Design, Practice and Considerations for MBR Retrofit.
- Applicability of MBR for Industrial Anaerobic Treatment.

APPENDIX V

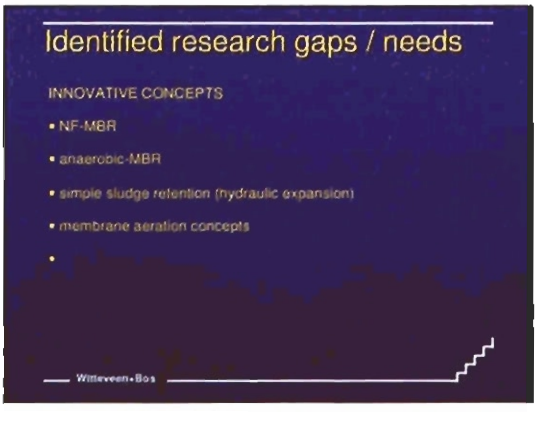
SUMMARY WORKSHOP DAY 1

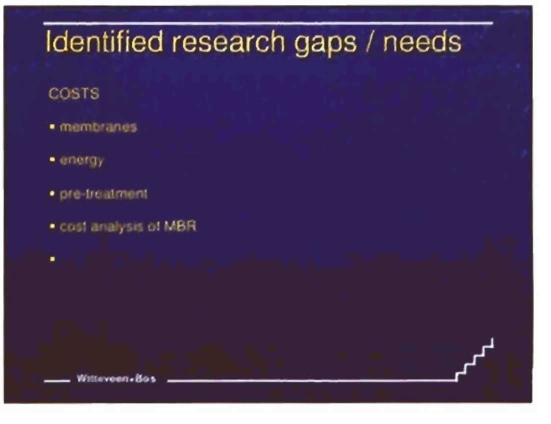

Identified research gaps / needs
EFFLUENT QUALITY
• effects from activated sludge processes in MBR
• effects from solids / colloidal separation in MBR
Witteveen+Bos

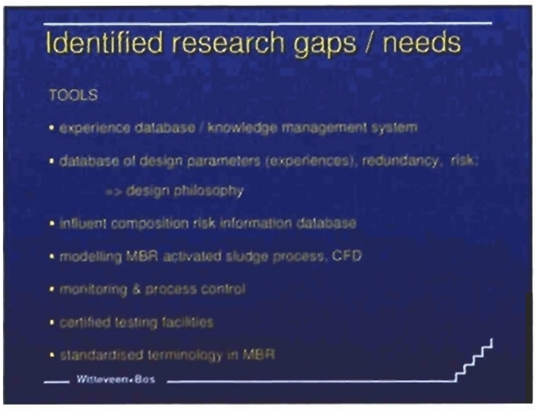

Identified research gaps / needs
FOULING
• activated sludge / feedwater characteristics
• physical / chemical interactions MEM - SLUDGE WATER
• feedwater conditioning
• membrane conditioning
Witteveen+Bos


Identified research gaps / needs
MEMBRANE CLEANING
• physical issues of cleaning
• chemical issues of cleaning
• cleaning agents (chemicals, oxidants, enzymes)
• cleaning methods (type, dosage, time, temperature, pH)
• cleaning methodologies
Witteveen+Bos

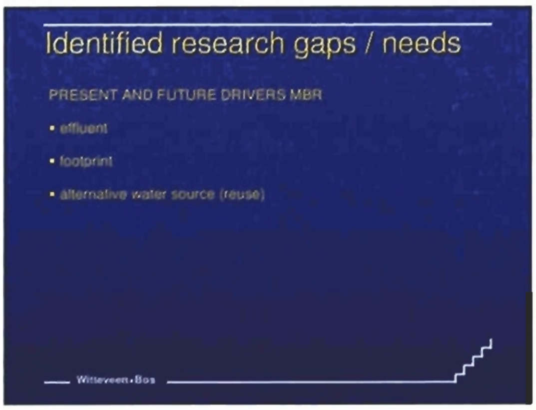

Identified research gaps / needs
DESIGN & OPERATIONAL ISSUES
• coping with hydraulic fluctuation
• energy consumption
• screening & solids handling and disposal
• activated sludge design
• pre-treatment
• scale (up / down) issues
• membrane characteristics i.r.t. lifetime
• retrofit, hybrid, process
Witteveen+Bos

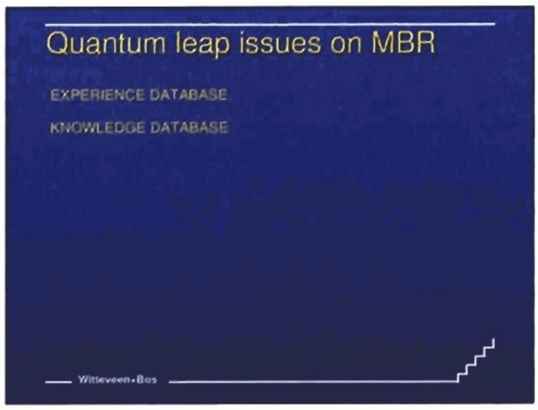

Identified research gaps / needs
INNOVATIVE CONCEPTS
• NF-MBR
• anaerobic-MBR
• simple sludge retention (hydraulic expansion)
• membrane aeration concepts
Witteveen+Bos


Identified research gaps / needs
COSTS
• membranes
• energy
• pre-treatment
• cost analysis of MBR
Witteveen+Bos


Identified research gaps / needs
TOOLS
• experience database / knowledge management system
• database of design parameters (experiences), redundancy, risk:
=> design philosophy
• influent composition risk information database
• modelling MBR activated sludge process, CFD
• monitoring & process control
• certified testing facilities
• standardised terminology in MBR
Witteveen+Bos


Identified research gaps / needs
DECISION ANALYSIS MBR <=> CAS
• life cycle analysis
• energy analysis
• cost analysis
• reliability
• public acceptance
Witteveen+Bos


Identified research gaps / needs
PRESENT AND FUTURE DRIVERS MBR
• effluent
• footprint
• alternative water source (reuse)
Witteveen+Bos


Quantum leap issues on MBR
EXPERIENCE DATABASE
KNOWLEDGE DATABASE
Witteveen+Bos

APPENDIX VI

DRAFT RESEARCH PROPOSALS

GWRC Workshop Membrane Bioreactors
25 - 27 April 2005

RESEARCH PROPOSAL (DRAFT)

Project Title:	***Decision Support Tool for municipal MBR technology choice***				
Name of Proposer & Affiliation:	GWRC (Pete Pearce, Thames Water)				
Collaborators:					
	2005	**2006**	**2007**	**Beyond**	**Total**
Estimated Total Cost of Research (Euro)		100'000 €			

	Justification:
Background:	MBR is an emerging new technology without clearly defined application boundaries compared with conventional technologies: MBR advantages are low footprint, disinfected and solids free effluent; disadvantages are energy requirement, cost, and process complexity. Up to date this technology choice for municipal applications was mainly driven by non commercial considerations. No standard procedure for technology selection is currently available.
Consequences if work not carried out:	In absence of an integrated decision support tool, approval for future installations will normally be based on subjective criteria, without thorough performance and economical considerations.
Benefits to be achieved: - Political - Economic - Technical	 Transparent and rational assessment procedure for technology selection Cost effective process selection including all relevant cost issues Allow the selection of appropriate technology according to the local requirements

	Objectives:
Aiming to achieve:	Develop a general evaluation procedure to allow the comparison of MBR with conventional and alternative technologies on a cost/performance basis for a broad spectrum of local conditions and requirements
Specific questions answered:	Is MBR the best process choice for a given application.
Tasks set for contractor:	Benchmark the costs and performance of MBRs against conventional solutions. Integrate the benchmarking results into a guideline to be used by decision makers.
Deliverables:	Simple decision tree based on technically boundary criteria to evaluate whether detailed investigations are required for considering MBR. In case of no evident choice basis, possible alternatives are to be outlined in terms of cost, energy footprint, personnel requirement, flexibility, sludge production and performance.
Completion date to maximise benefits:	End 2006
Target audience for the output?	Designers and decision makers, water industry end users
Which groups should receive any reports resulting from this work?	Utilities, consultants, research institutes
Should the output be submitted for independent peer review to add authority to the work?	By a European and an American consultants

GWRC Workshop Membrane Bioreactors
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RESEARCH PROPOSAL (DRAFT)

Project Title:	***Development of an MBR knowledge base for municipal wastewater treatment***				
Name of Proposer & Affiliation:	Cora Uijterlinde (STOWA)				
Collaborators:					
	2005	**2006**	**2007**	**Beyond**	**Total**
Estimated Total Cost of Research (Euro)		200,000	200,000		400,000
Yearly update					25,000

Background:	**Justification:** Due to its perceived advantages, within the past decade there have been many MBRs installed. Much of the information and lessons learned that was obtained with these installations has not been published or otherwise communicated. The website database on MBR, developed by WERF, provides some information in this regard, but not the detailed information of global end users which is aimed at with this knowledge base. The structure of the knowledge base on MF, developed by AwwaRF, should provide a good basis for further development.
Consequences if work not carried out:	Repeated mistakes, operational failures. Limitation of developments.
Benefits to be achieved:	Speed up of technology; product improvement. Input for decision makers.
- Political	It provides a platform for an objective analysis of the technology. MBR technology will become more accepted.
- Economic	Decrease both capital and operational cost of MBR technology; Optimise design.
- Technical	For people owning/operating MBRs: it helps optimising operation For people planning to install MBR, it helps decision making. Exchange of operational information, which leads to more efficient design, operation and overall application of the MBR technique. Further research can be focused more accurately.

	Objectives:
Aiming to achieve:	Sharing of knowledge with target audience.
Specific questions answered:	What are the lessons learned What are the monitoring tools What are the process control tools, operational issues, etc.
Tasks set for contractor:	• Develop a global team of stakeholders. • Identify parameters, information to become available. • Definition of terminology • Preparation of a questionnaire. • Implementing of questionnaire in a website. • Contacting utilities/users for filling up questionnaires. • Follow up interviews/phone calls etc. • Quality control of delivered data. • Data analysis • Build and maintain website, 'spread the news' • Take care of confidentiality issues
Deliverables:	Website Final report
Completion date to maximise benefits:	24 months needed, finish early 2008
Target audience for the output?	End users (waterboards, water utilities), designers, researchers, students, suppliers
Which groups should receive any reports resulting from this work?	GWRC members
Should the output be submitted for independent peer review to add authority to the work?	Yes. Presentation at an international conferences

GWRC Workshop Membrane Bioreactors
25 – 27 April 2005

RESEARCH PROPOSAL (DRAFT)

Project Title:	***Effluent quality of MBRs***				
Name of Proposer & Affiliation:	GWRC (Adriano Joss, EAWAG)				
Collaborators:					
	2005	**2006**	**2007**	**Beyond**	**Total**
Estimated Total Cost of Research (Euro)	**€ 30'000**				

	Justification:
Background:	Claims on MBRs effluent quality are often overestimated. Clear data are required in terms of nutrients, micropollutants and disinfection
Consequences if work not carried out:	Wrong process choice due to lack of knowledge on wastewater treatment performance by MBR connected to high costs.
Benefits to be achieved:	
- Political	Realistically demonstrate the capability of MBRs to remove specific wastewater constituents. Enable appropriate regulation (BAT).
- Economic	Avoid misinvestments
- Technical	Better understanding of capability of the MBR technology

	Objectives:
Aiming to achieve:	Overview of the current data on the following municipal MBR effluent quality parameters: pathogens, organic and inorganic micropollutants, nutrients, organics
Specific questions answered:	Comparison to conventional wastewater treatment is to be given. Details on nutrient removal at low to very low concentration are to be discussed as well as the pollutant fractionation.
Tasks set for contractor:	Collect existing published and unpublished data and identify knowledge gaps. A comparison to conventional wastewater treatment alternatives is to be outlined.
Deliverables:	Summary of relevant data tables including source references and final statement on MBR capability.
Completion date to maximise benefits:	End of 2005
Target audience for the output?	MBR decision makers and stakeholders
Which groups should receive any reports resulting from this work?	Consultants, research institutes
Should the output be submitted for independent peer review to add authority to the work?	By a European and an American consultants

GWRC Workshop Membrane Bioreactors
25 - 27 April 2005

RESEARCH PROPOSAL (FINAL DRAFT)

Project Title:	***Scenario studies 2030: Identification of future concepts of wastewater management with innovative MBR technologies***				
Name of Proposer & Affiliation:	Boris Lesjean (KWB)				
Collaborators:					
	2005	**2006**	**2007**	**Beyond**	**Total**
Estimated Total Cost of Research (Euro)		120,000			120,000

	Justification:
Background:	MBR technology has almost reached maturity and the status of proven technology. Footprint reduction, disinfected effluent and overall stable effluent quality are among the main drivers for its current application level. Nevertheless, further development of the technology is still needed to expand the potential application of MBRs. In addition, the sanitation approach is developing towards decentralised applications with closed loops of water, energy and nutrients recovery ("Ecosan concepts"). Novel MBR technologies may be very appropriate for the implementation of these new concepts or to improve the treatment performance of current MBR processes (e.g. trace organics), such as NF-MBR, anaerobic MBR, ceramic MBR, membrane aeration bioreactor, membrane biofilm reactor, etc.
Consequences if work not carried out:	Stagnation of MBR technology development. Lack of global visibility on emerging membrane technologies for municipal wastewater treatment. Reduced development of alternative and decentralised sanitation concepts.
Benefits to be achieved:	
- Political	Increasing sustainability of water cycle. Contribution to UN Millennium Goals with alternative membrane concepts.
- Economic	Development of more cost effective treatment systems (for cities and industries). Indirect benefits of water, energy and nutrients reuse.
- Technical	More options for solving water problems. Creating options for reuse, closing water cycle.

	Objectives:
Aiming to achieve:	Identification of new concepts applying MBR and appropriate innovative membrane technologies.
Specific questions answered:	What are the scenarios for wastewater (and water) management anticipated in 2030 in different regions of the world? (urban/rural, climate, existing infrastructure, developing countries etc) How may these scenarios integrate the MBR technology, or innovative membrane processes? (emphasis on usability of different qualities of effluent, and/or recovery potential) Which innovative MBR technologies look promising for the future sanitation concepts and should concentrate world-wide efforts for further developments?

Tasks set for contractor:	• Literature review
	  o MBR innovative concepts: performances, costs, expectations
	  o Alternative sanitation concepts, particularly those including MBR systems
	• Workshop of creative global experts in relevant fields (e.g. practical, scientific, material science, nanotechnology, anaerobic, reuse, sociology, integrated water resource management, sanitation in developing countries etc) to identify innovative concepts and appropriate MBR-based technologies (secrecy agreement!)
	• Prioritise concepts, select most promising for further analysis
	• Desktop study on selected concepts (incl. Preliminary cost-benefit)
	• **Final report**

Deliverables:	Final report, identifying innovative concepts and technologies
Completion date to maximise benefits:	12 months, finish early 2007
Target audience for the output?	GWRC members, universities, industry, vendors, NGO
Which groups should receive any reports resulting from this work?	GWRC
Should the output be submitted for independent peer review to add authority to the work?	Internal review / quality management from selected experts (workshop) Presentation at an international conference

APPENDIX VII

PRESENTATION FOLLOW UP

Global Water Research Coalition

Workshop MBR

Varseveld, 25-27 April, 2005

Goals

- GWRC research agenda based on members needs
- **Research strategy for priority issues**
  - **Review of existing knowledge and activities**
  - **Workshop about knowledge gaps and research needs**
  - **Portfolio of research projects**
- Tailor made project teams with one member as lead agent
- Sharing the results within the GWRC
- Knowledge transfer to stakeholders by the members

Project Proposals

- Decision Support Tool for municipal MBR technology choice
- MBR Knowledge Base for municipal wastewater treatment
- Effluent quality
- Innovative MBR in future concepts of the urban water cycle

Project Proposals

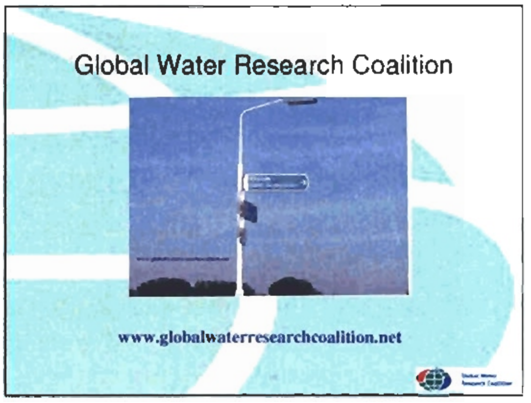
- Follow up
  - Finals drafts by 15 May
  - Review by all participants by 15 June
  - Final proposals by 1 July
  - Send to all workshop participants
  - Together with research strategy => Board approval
  - Inventory of formal member commitments
  - Contacts with additional contributors: IWA, ATV, ...

Actions agreed

- Explore the need/possibilities of a certification and testing body
- EU consortium to deliver "set of terminology"
- Secure link between EU consortium ⇔ GWRC with respect to fouling & cleaning and design & operational issues
- Exchange of information
  - Member section GWRC website

Follow up

- State of the Science report (final draft 31 May)
  - 6 areas as chapters, included regional perspectives, ...)
  - Final review by participants by 1 July)
- Workshop report (draft by 31 May)
  - Process
  - Map of knowledge
  - Gaps and needs => priorities and research strategy
  - Suite of project proposals
  - Presentations as annex (pdf)
  - Review by participants by 1 July)
- Research strategy and priority projects to Board
- Inventory of member participation in projects


Global Water Research Coalition
www.globalwaterresearchcoalition.net

Global Water Research Coalition
c/o International Water Association
Alliance House
12 Caxton Street
London SW1H 0QS
United Kingdom
tel: +44 207 654 5545
email: gwrc@iwahq.org.uk
www.globalwaterresearchcoalition.net